GGIG Graphical Interface Generator

Programming Guide

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The following report is the outcome of a collaborative effort of University Bonn and the author. Larger parts of the Java code underlying GGIG had been developed over the years in the content of the CAPRI modelling system, which receive considerably funds from the EU research framework programs. Following the general policy in CAPRI, the GGIG pre-compiled code can be used for other scientific projects as well.

The author would like to acknowledge the contribution of Alexander Gocht, vTI Braunschweig, to the CAPRI GUI coding efforts. All errors remain with the author.

Content

Overview

The GAMS Graphical Interface Generator (GGIG) is a tool to generate a basic Graphical User Interface (GUI) for a GAMS or R project[1] with five main functionalities:

1. **Generation of user operable graphical controls from XML based definitions**. The XML file defines the project specific layout of the GUI. The user can then interact with the GUI to change the state of the controls. The state of each control component such as a checkbox can then be mapped to GAMS code ($SETGLOBALS, Set definitions, settings for parameters). It combines hence the basic functionality of a GUI generator and a rudimentary GAMS code generator.
2. **Generation of GAMS compatible meta data** from the state of the control which can be stored in GAMS GDX format and later accessed, so that scenario definitions are automatically stored along with results.
3. **Execution of a GAMS or R project while passing the state of the control to GAMS respectively R** as a include file**.**
4. **Exploitation of results from GAMS runs** by providing an interface to define the necessary interfacing definitions in text file to load results from a GAMS into the CAPRI exploitation tools.
5. **Access to a set of GAMS related utilities.** This include e.g. a viewer for GDX files, a utility to build a HTML based documentation of the GAMS code or a batch execution utility.

GGIG is steered with xml-based text file and does not require knowledge in a higher programming language

GGIG was developed to overcome a typical problem when economic models are implemented in GAMS. GAMS itself, not at least to ensure platform portability, does not allow for graphical user input. Run specific settings for GAMS need therefore to be introduced either by changes to the GAMS project code itself or by adding settings of environment variables to the GAMS call. Experienced model users – typically the code developers themselves – know how to change run specific settings in the GAMS code, and do so typically quite efficiently.

[1] The code can also be used from inside Java, but that feature is not discussed in the documentation.

As a consequence, they seldom feel the need to develop a GUI steering their GAMS project. The need to invest in GUI development might have even decreased as the GAMS IDE now offers some basic functionality often found in project specific GUIs. The IDE allows inter alia starting GAMS, inspecting parameters found in the listing file or viewing the context of a GDX file.

However, a GAMS code only solution for an economic model typically poses a serious entry barrier to newcomers for two reasons. Firstly, possible users are often not familiar with GAMS. But even with some elementary knowledge of the language, they might face problems understanding project specific GAMS code making use of advanced GAMS features. Secondly, they face the challenge to familiarize themselves with the specific code of the project. They would need to learn enough to know exactly which specific code changes are necessary to implement e.g. scenarios in a given project. In some cases, the large and/or complex GAMS code of projects basically excludes their usage beyond some core developers. Accordingly, institutions or tool developers often observe that promising tools are only used by a few specialists, reducing returns to their investment in tool development and maintenance. Possible other users often shy away from the high learning costs and/or fear to generate, analyse and present results based on a black box where it is unclear how to enter exactly a scenario and how to access their results.

It is therefore not astonishing that some tools based on GAMS (and also on other modelling languages) have developed their specific GUIs. These GUIs let the user steer the tool with a touch & feel comparable to other programs running on modern windowed operating systems. However, writing a GUI for a larger project firstly requires considerable programming skills, often not found with the economic modellers themselves. Secondly, developing a good design, coding, debugging and maintaining a GUI can be a rather costly exercise. As a consequence, typically only rather large and well funded tools have found and invested the necessary resources to develop such GUIs. CAPRI and runGTAP provide some examples. These project specific GUIs are typically very powerful, but tend also to be tool specific. They can typically not be modified easily to fit to another (GAMS) project.

That renders it inviting to think about generic tools able to generate a GUI which can interface to GAMS. The coding effort can then be shared across projects, and user might even reduce learning costs if they use similar GUIs for different tools. A well-established example for such a tool is the “GAMS Simulation Environment (GSE)” by Wietse Dol. GSE is quite general: it incorporates features of an Integrated Development Interface (IDE) as well as exploitation features. It is based on specific “tags” introduced in the GAMS code. GGIG is certainly not a competitor to GSE: GSE offers more functionality and is more IDE oriented. It might however be easier to embed some simple steering settings with GGIG into an existing project compared to the tag based concept of GSE. GSE was in the past a commercial product distributed with a license but can now be downloaded for free.

An example of a completely different approach to a GUI for modelling tools offers SEAMLESS-IF with its focus on component linkage. Based on OpenMI, it however requires the development of an OpenMi compatible wrapper around the GAMS project itself. Concepts such as the SEAMLESS-IF are therefore probably only suitable for larger projects focusing on combining components based on different programming languages. Furthermore, SEAMLESS-IF is based on a client/server implementation and requires specific software licences for deployment.

GGIG might hence be seen as a quite simple and easy to use tool to generate GUIs for GAMS projects. If all GGIG features are used, it can however host quite complex projects. The new GUI for CAPRI built with GGIG offers an example for a rather complex implementation.

As mentioned above, a second important contribution of GGIG is to mechanize to the largest extent the generation, storage and later inspection of meta data underlying a scenario and the related result set, overcoming an often encountered weakness in (economic) models.

And thirdly, GGIG offers a bridge between the powerful CAPRI exploitation tools and other GAMS based models. It draws on the experiences with BenImpact, MIVAD and the village CGEs developed in Advanced-Eval, GAMS tools models resp. Java based GUIs where the CAPRI exploitation tools had been used. These GAMS based projects used the CAPRI exploitations, but did not add any GUI functionalities to also steer their models. The experiences with these examples can hence be seen as the starting point for the development of GGIG in order to expand beyond a pure, project adjusted implementation of the CAPRI exploitation tools.

Some specific skills and eventually serious refactoring of the reporting part of an existing model are necessary to benefit from the full functionality of the CAPRI exploitation tool. It therefore pays typically off to start using GGIG for exploitation from the beginning. But at least, no skills in coding in a higher programming language such as Java are necessary to define the necessary interfaces between the GAMS project and the exploitation part. The latter offers interlinked tables (with selections, sorting, outlier control, pivoting), different type of graphs, maps and flow maps.

Additionally, GGIG features a set of utilities originally developed for CAPRI such as HTML based documentation of the GAMS code, a GDX viewer or a batch processing mode.

The development of GGIG would have been impossible without the continued funding for the maintenance and development of CAPRI by the EU Commission, which also let to the emergence of the CAPRI GUI and exploitation tools. That code base was the starting point for GGIG. I would also like to mention the contribution of Alexander Gocht over the last years to the code of the interface.

The main parts of GGIG are graphically depicted below. At its core stands the GGIG Control generator, based on Java code. Based on a XML based definition file provided by the project, it generates a project specific GUI which can be operated by the user. The state of these controls such as numerical settings, on/off settings or n of m selection can be passed to GAMS by an automatically generated include file which also contains automatically generated meta data. The user can also execute GAMS from the GUI. The GUI can equally load numerical results and meta data in a specific GDX viewer. The latter supports "view definition", i.e. pre-defined reports to exploit the results. The details of the different elements are discussed below.

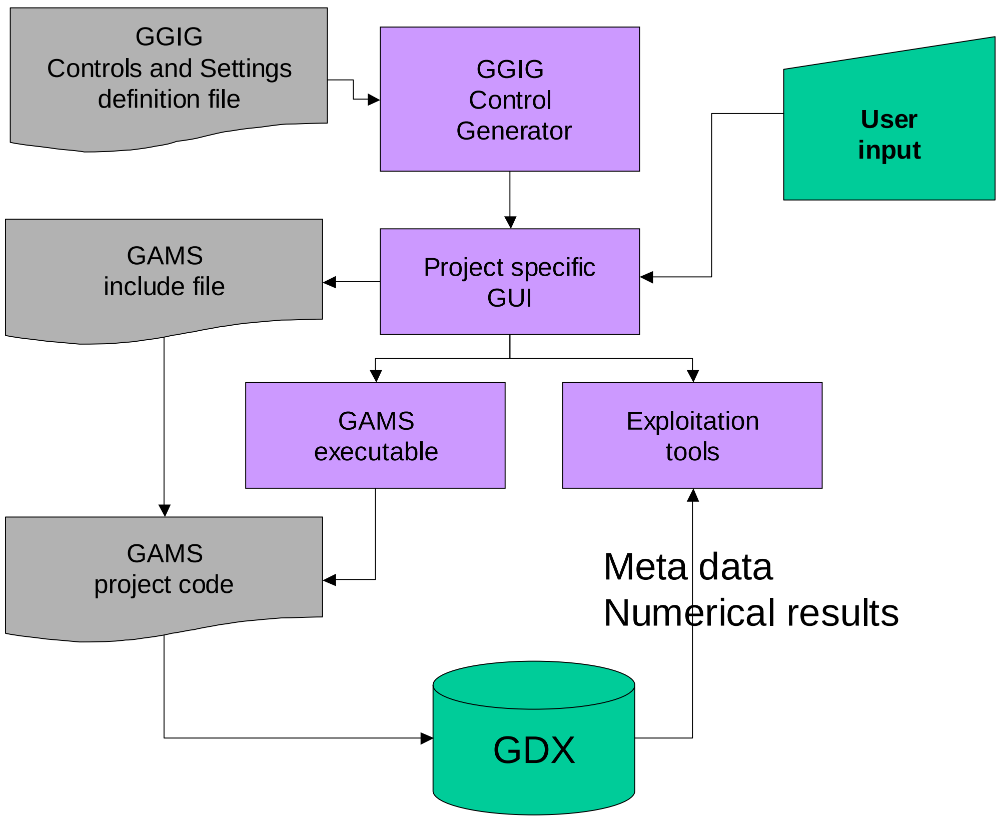


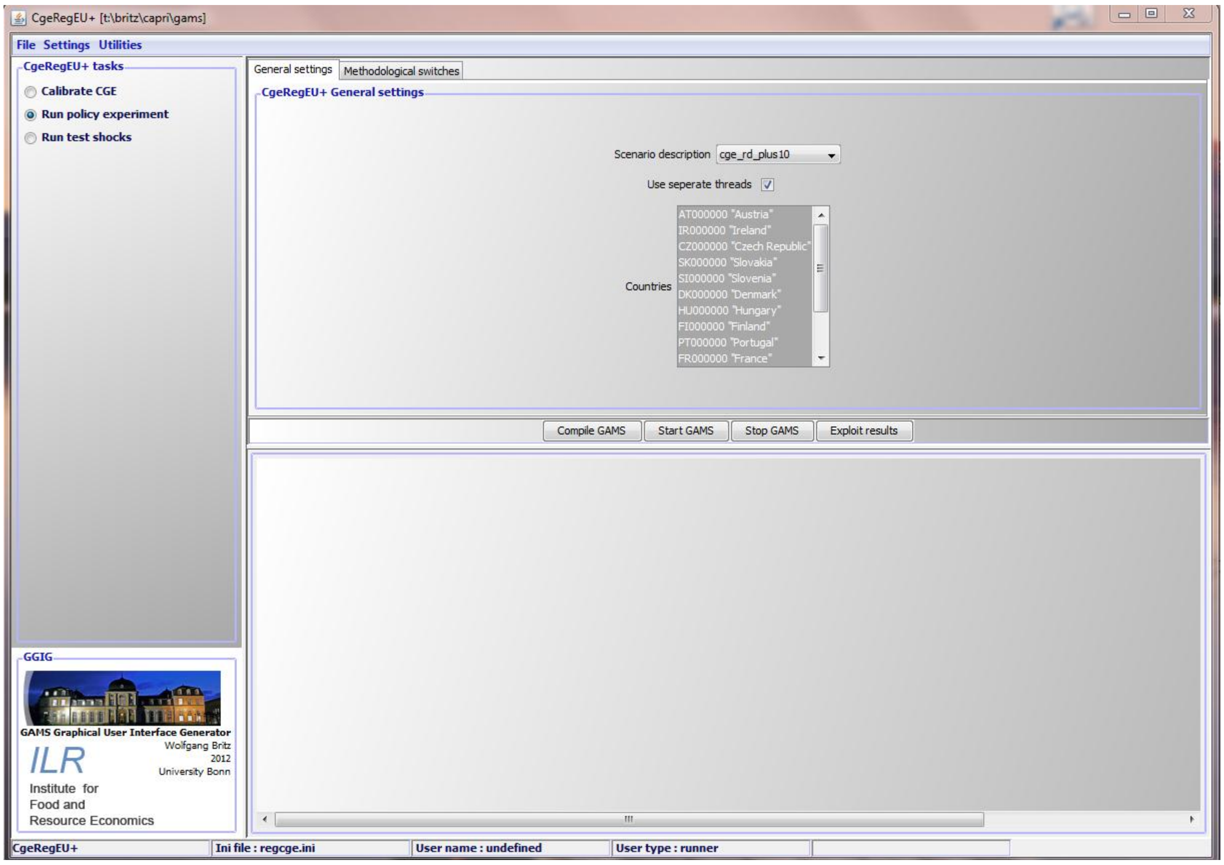
Diagram: Overview on information flow in GGIG

Current applications of GGIG

Since the first prototype, GGIG has been successfully implemented in a number of projects, examples are listed below:

- DairyDyn: an fully dynamic single farm model focusing on the impact of Green House Gas emission indicators on allocation and investment decision
- A small, spatial multi-commodity model for world trade of cooked and uncooked poultry meat with a focus on trade bans related to Avian Influenca
- A EU wide layer of regional CGEs with a focus on Rural Development measures on the second pillar of the CAP, which is now incorporated into CAPRI.
- LANA-HEBAMO: A Hydro-Economic model for the lake Naivasha in Kenya.
- The FADNTOOL project which combines a set of economic tools for simulating policy impacts based on the FADN data.
- An user interface augmented version of GTAP in GAMS.
- An Agent Based model for structural change in agriculture, which is realized in GAMS, but uses GGIG as its user interface.

An overview on the GUI



Run policy experiment [✓]

Scenario description: cge_rd_plus10

Use seperate threads ✓

Countries:
AT000000 "Austria"
IR000000 "Ireland"
CZ000000 "Czech Republic"
SK000000 "Slovakia"
SI000000 "Slovenia"
DK000000 "Denmark"
HU000000 "Hungary"
FI000000 "Finland"
PT000000 "Portugal"
FR000000 "France"

CgeRegEU+ | Ini file : regcge.ini | User name : undefined | User type : runner

As shown in the example above, the GUI consists a few elements:

1. A **menu bar** which allows to change some settings (see the section on general interface settings)
2. A **workstep** and **task selection panel** on the left hand side where the user can select between different tasks belonging to the project.
3. A **right hand side panel** which either shows:
    i. **The generated controls**, a button panel to start GAMS and a windows in which the message log from GAMS is shown
    ii. **A panel to select data to view** and to start their exploitation
    iii. The **exploitation tools**
4. A small window in the left lower corner which present a logo.

Whereas the elements 1. and 3.ii and 3iii. are not project specific, the worksteps and tasks available in 2. and the controls shown to the user in 3.i. are generated in a project specific initialisation file. The details of that file – which is core of GGIG – are discussed below.

The interface generator

Tasks

Tasks are central elements in GGIG. Each control can belong to one or several task, and each task might have its own GAMS or R process. That allows steering even rather complex tools with one GUI which combine different GAMS or R projects. It supports a structured development of the GAMS/R code as either separate GAMS/R files with a clear purpose are generated or a GAMS/R file consists of blocks which belong to certain tasks.

When the user selects a task, only the controls belonging to that task are shown to the user, easing the handling of the GUI.

Mapping controls setting to GAMS

Controls are user operable, graphical elements. A few examples are shown below.

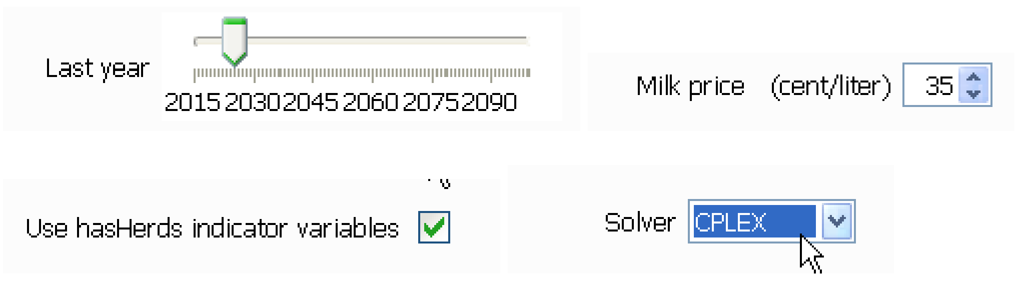

Last year
2015 2030 2045 2060 2075 2090
Milk price (cent/liter) 35
Use hasHerds indicator variables ✓
Solver CPLEX

Diagram: **Example of controls generated with GGIG**

In the case of GGIG, these graphical controls are used by the user to define textual and numerical settings which in turn define run specific settings for a GAMS/R project. GGIG offers five functionalities related to these controls and their interactions with a GAMS project:

1. It *generates the controls* from a definition file on a windowed program interface.
2. It offers the necessary code to *intercept user operations* on the controls.
3. It maps the settings of the controls based on the user input to as sequence of *GAMS or R statements*, which can be included into a GAMS/R project to generate a specific run.
4. It allows *execution of GAMS or R*.
5. It offers a GDX viewer which supports the definition of *pre-defined reports*.

The overview on the process is shown in the diagram above.

In order to allow the run specific settings to enter a specific GAMS project, the generated include file should define the sole entry point of run specific information. The state of the controls – passed to the include file - should hence define all the necessary information for a specific run. The GAMS code should accordingly not allow for or require additional changes to generate a “scenario”, i.e. a specific run. It is however easily to use a text control to enter the directly the name of a include file.

The generated include file is overwritten each time the user starts the GAMS project.

Basic concept of the control definition file

GGIG supports two formats for definitions file: XML based property files or standard Java property files. The later are only supported for backward compatibility and should no longer be used for new GGIG projects.

XML property file

The core of GGIG consists of the control definition file. The XML property file defines a controls, tasks, etc. based on XML tags. As the XML file is parsed by a standard Java XML parser, these tags can additional by stored in different lines, see example below:

```
<control>
         <order>1110</order>
         <Type>singlelist</Type>
         <Title>First year</Title>
         <Value>1984</Value>
         <Options>1984,1985,1986,1987,1988,1989,1990,1991,1992,1993,1994,1995,1996,</Options>
         <gamsName>FirstYear</gamsName>
         <tasks>Prepare national database,
         Finish national database,
         FSS selection routine,
         Build regional time series,
         Build regional database,
         Build global database,
         Generate trend projection,
         Generate farm type trends,
         </tasks>
</control>
```

The different tags (or keywords) are discussed in detail below.

Standard Java property files (deprecated)

It follows the basic implementation of a property file in Java. Each line thus consists of a key – value pair, separated by an equal sign. The definition of the controls is stored in the same file along with general settings such as the name of the GAMS project, directories, the user name etc..

For each control, one line is used. That line comprises all the necessary information to generate the control, as well as to store the current setting.

The control definition file is text based and can hence be edited with any text editor. Most of the settings – with the exemption of the definitions of the controls themselves – can also be entered by the user via the controls on the GGIG interface. These project independent controls are to a larger extent borrowed from the CAPRI user interface. On top, a first rudimentary control editor is embedded in the tool.

Call of GGIG

In a normal installation, there are two files:

1. One default file with the control definitions and related default values. That file should be typically under version control.
2. A second file which is installation specific, it will solely store the values entered by the user on the interface and will be in ini format. Its content is updated each time the interface is closed, the next run will re-load the control and other setting from that file.

A typical call will therefore look like:

```
Java Gig.jar project.ini project_default.xml
```

Where the project ini stores the current user settings and the second one the control and further project specific settings. It is hence possible to host several GGIG based installations in one directory where the jars etc., are stored.

Tool name, logo and background color

The following three XML tags allow to set the tool name, the logo shown on the interface and the background color:

```
<toolName><attr>FADNTOOL</attr></toolName>
<logo><attr>fadntool_logo.jpg</attr></logo>

<backgroundColor><attr>255,140,180</attr></backgroundColor>
```

Equally, the icon shown in the task bar can be set

```
<icon><attr>dairydyn.gif</attr></icon>
```

Worksteps

Worksteps allow to group tasks, and thus represent the top level of structuring actions in a tool. The following attributes are possible

Name	Name of the workstep shown as selectable radio button (required)

Tasks	List of tasks

```
<workstep>
         <name>Build database</name>
         <tasks>Prepare national database,
                Finish national database,
                FSS selection routine,
                Build regional time series,
                Build regional database,
                Build global database,
                Build HSMU database
         </tasks>
</workstep>
```

The work step selection is based on a set of radio buttons in a panel in the upper left corner of the generated GUI. It is not necessary to define work steps in a project.

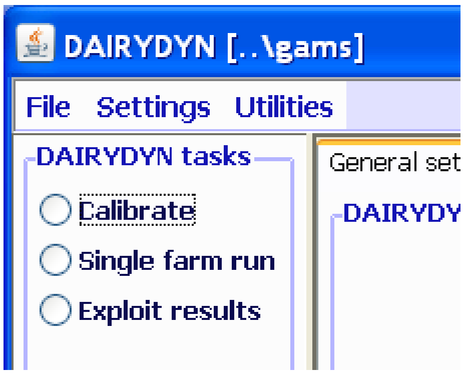
Tasks

The control definition file must define a list of tasks (such as calibrating the model and running the model) for the project.

A task can have its own GAMS or R file to start, its own result directories and its own set of controls. Each control can be shared by several tasks.

```
<task>
         <name>Run test shocks with CGE</name>
         <gamsFile>regcge.gms</gamsFile>
         <incFile>regcge_settings</incFile>
         <regionDim>0</regionDim>
         <Dim5Dim>1</Dim5Dim>
         <activityDim>2</activityDim>
         <productDim>3</productDim>
         <scenDim>4</scenDim>
         <yearDim>5</yearDim>
         <useMeta>true</useMeta>
         <resdir>regcge</resdir>
         <filemask>res_[0-9]{4}testShocks.{1}gdx$</filemask>
</task>
```

The tasks are put in the order as they are defined in the control file on the left hand side of the interface, below the work step panel (if work steps are defined):



The following attributes are possible for a task

Name	defines the name of task, shown on interface (required)
gamsFile	defines the name of the GAMS project to start (optional)
resDir	result directory where the results are stored (optional)
filemask	regex string used filter the files shown in the scenario exploitation boxes for the task (required)
incFile	defines the name of include file used by the task (optional)
gdxsymbol	defines the GAMS symbol (set, parameter) to load for exploitation
{logical}dim	position of the logical dim in gdxsymbol, where logical=region, activity, product, year, scen, dim5
filters	filters for scenario input, see below

If no *gamsFile,incFile* or *resDir* are given, the general ones defined in the ini-file are used.

Tasks without a GAMS or R clearly cannot be executed, but they can be used to exploit GDX files. That allows to e.g. to explore different parts of data bases.

Use of filters for exploitations

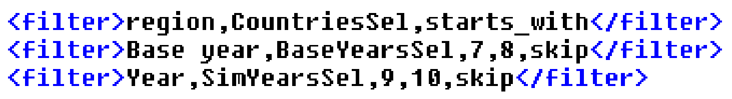
Filters are used to

1. To let the user select from the GDX files which are potentially generated by the task based on a specific content selection, .e.g. only files from a specific year
2. To introduce a filter on the GDX element loaded in the viewer, e.g. to only load records for a specific country

A filter definition consists of 3 fields:

1. The logical dimension to which it is applied: {region, activity, product, year, scen, dim5}
2. The selection control which is used for the filter
3. The type of filter:
    a. **“Starts_with” or “ends_with” for GDX element filters**, i.e. only such records will be loaded where the item describing the logical dimension starts with one of the selected keys.
    b. Otherwise, a pair of integer values which describe on which position of the file names the selected key should be found plus either “skip” for only using selecting files or “merge” to merge records from the chosen GDXs.

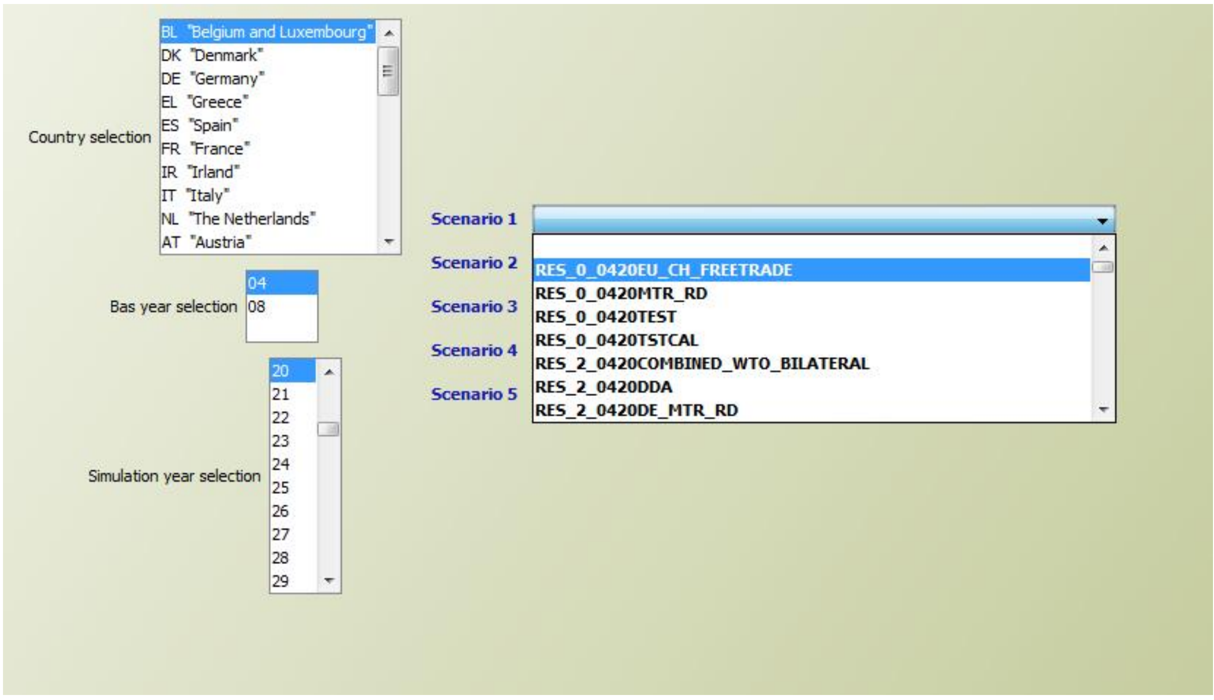
The screenshot below shows an example generated from the following filters:



```
<filter>region,CountriesSel,starts_with</filter>
<filter>Base year,BaseYearsSel,7,8,skip</filter>
<filter>Year,SimYearsSel,9,10,skip</filter>
```

The first filter “starts_with” does not affect the file selection, but will affect which records from the selected files are loaded in the viewer. In the example shown below, where the filter controls fit to the definitions above, only records where the region key starts with “BL” will be shown to the users.

The other two filters will skip files where the base and simulation years do not match the selection. In our example, the base year is stored as a two digit key on position 7 and 8, and only files with a “04” are in the drop down box for the scenarios. Similarly, only results for the simulation year “20” are selected.



Normally, the name of the file will be used to characterize the “scenario”. The “merge” is made for the case where several GDX files should be combined and the file name does not distinguish model runs. An example offers the downscaling component of CAPRI: it produces in separate GAMS run for the same scenario one file for each country which comprise rather huge data sets. The “merge” mode allows combining these result sets together.

Controls

Possible fields for controls

The necessary information for each control is stored in different tags for each control definition file. The controls are put on the interface in the order they are given in the XML. The following fields are available:

Type	defines the type of control (required). The different types are discussed below in detail.
Title	defines the description of the control as seen by user (required)
GamsName	defines the name of global settings resp. SET name (optional)
Value	pre-selected setting(s) (optional)
Options	list of available options (required where applicable)
Range	Min, max, increment, major ticks; or number of rows shown (required where applicable)
Tasks	List of tasks to which the control belongs. If empty, it belongs to all tasks
Tooltip	A tooltip text hovering over the control
Pdflink	Link to a pdf file and chapter to open on mouse over
Selgroups	Selection list opened by pop-up menu (see Multilist control)
Style	Different style options (optional)
Disable	Control is blocked for input – useful to show settings on interface which are should be sent to GAMS for a specific task.

Type of controls

The following types of controls are available. The related JAVA swing JComponent is shown in bracket.

Tab	Introduces a new tab on the tabbed plane hosting the controls
Separator	to structure a pane with control (JLabel in an JPanel with a border)
Panel	the next controls are shown together on a panel
Text	to enter a free text (JTextField)
Checkbox	for on-off type of settings (JCheckBox)
Singlelist	for 1 of n selections (JList in a JScrollPane)
RadioButtons	for 1 of n selections (Group in JButton, vertically aligned)
Filesel	for 1 of n selections of a list of files (JList in a JScrollPane)
FileselDir	for 1 of n selections of a list of files found potentially in sub-directories, preceded by a sub-directory lists (two JList in a JScrollPane)
Multilist	for n of m selections (n=0..m), (non editable JComboBox)
MultilistNonZero	for n of m selections (n=1...m), (non editable JComboBox)
Slider	for integer value selection from a range of values (JSlider)
Spinner	for floating or integer value selection from a range of values (JSpinner)
Table	to enter floating point variables in a two or three-dimension parameter, comprises pivot possibilities (JTable)
SimpleTable	to enter floating point variables in a two or three-dimension parameter, no pivot possibilities (JTable)

Tab

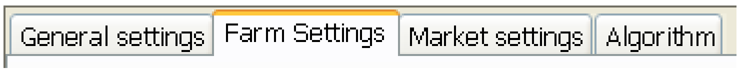
Purpose

Used to structure the interface by grouping controls on an input pane: introduces a new tabbed plane to which controls following are then added

Applicable fields:

Title, Tasks

Control optic:



Remark:

The user can only see one of the tab pane at any time – care should hence be given to keep the number of tabs and the assignment of controls to tabs such that a user can easily check all key inputs.

Separator

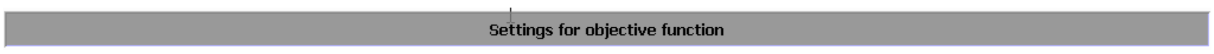
Purpose

Used to structure the interface, gives a title for the next block of controls

Applicable fields:

Title, Value, Tasks

Control optic:



Example definition:

```
<control>
        <order>2010</order>
        <Type>Separator</Type>
        <Title>Supply model</Title>
        <tasks>Baseline calibration market model,
        Baseline calibration supply models,
        Run scenario with market model,Generate expost results
        Run scenario without market model</tasks>
</control>
```

Text

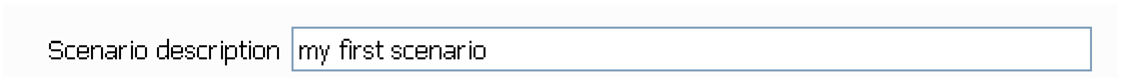
Purpose

Allows the user to enter text. Used e.g. to name the output generated by a run.

Applicable fields:

Title, Value, Tasks, Style

Control optic:



Possible value:

Any text allowed

User action:

Edit with keyboard

Example definition:

```
<control>
         <order>1450</order>
         <Type>text</Type>
         <Title>Alternative GAMS license file for GHG emission estimation</Title>
         <Value>gamslice_cplex</Value>
         <Options> </Options>
         <range>0</range>
         <gamsName>altLicense</gamsName>
         <tasks>Baseline calibration market model,Run scenario with market model,Generate expost results</tasks>
</control>
```

Output to GAMS:

```
$SETGLOBAL Scenario_description my first scenario
```

Note:

If the text entered refers to an existing file, it is recommended to use a filesel control instead.

Checkbox

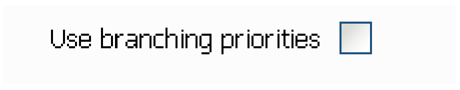
Purpose

Used for on/off settings, i.e. in cases where one of two options must be chosen, e.g. in cases of project modules which can be used or not (1 of 2). Cannot be used for 1 of n selections where n > 2 – use a List instead.

Applicable fields:

Title, GamsName, Value, Tasks, Style

Control optic:



Possible value:

true, false

User action:

tick / untick box with mouse

Example definition:

```
    <control>
             <order>1020</order>
             <Type>checkBox</Type>
             <Title>Generate GAMS child processes on different threads</Title>
             <Value>true</Value>
             <gamsName>threads</gamsName>
             <tasks>
                    Build HSMU database,
                    Run scenario with market model,Generate expost results
                    Run scenario without market model,
                    Baseline calibration supply models,
                    HSMU baseline,
                    Downscale scenario results,
             </tasks>
    </control>
```

Output to GAMS:

```
$SETGLOBAL Priorities false
```

Singelist

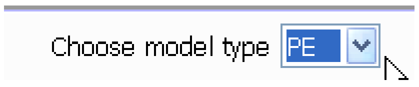
Purpose

Used for 1 of n selections. Used in cases where more then 2 mutually exclusive values for a setting are available.

Applicable fields:

Title, GamsName, Value, Options, Tasks, Style

Control optic:



Note: Drop down list will appear if the user clicks on arrow.

Possible value:

Defined by options field

User action:

tick / untick one of the selection possibilities with mouse

Example definition:

```
<control>
         <order>1110</order>
         <Type>singlelist</Type>
         <Title>First year</Title>
         <Value>1984</Value>
         <Options>1984,1985,1986,1987,1988,1989,1990,1991,1992,1993,1994,1995,1996,</Options>
         <gamsName>FirstYear</gamsName>
         <tasks>Prepare national database,
         Finish national database,
         FSS selection routine,
         Build regional time series,
         Build regional database,
         Build global database,
         Generate trend projection,
         Generate farm type trends,
         </tasks>
</control>
```

Output to GAMS:

```
$SETGLOBAL Choose_model_type PE
```

Note: The user cannot deselect, i.e. one of the options is always active.

filesel

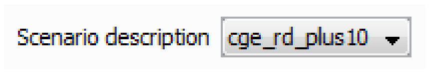
Purpose

Used for 1 of n selections of a list of files. That is e.g. interesting when the user can chose from a list of pre-existing scenario definitions in GAMS files.

Applicable fields:

Title, GamsName, Value, Options, Tasks, Style

Control optic:



Note: Drop down list will appear if the user clicks on arrow.

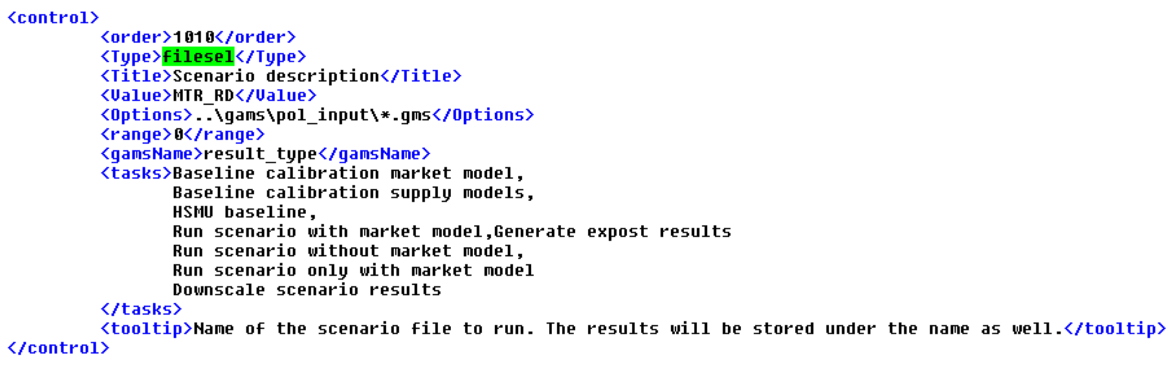
Possible value:

Defined by the file selection string in options field, .e.g ..\\gams\\pol_input\\cge_*.gms. The file extension fill be automatically removed from the items.

User action:

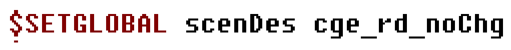
tick / untick one of the selection possibilities with mouse

Example definition:



```
<control>
         <order>1010</order>
         <Type>filesel</Type>
         <Title>Scenario description</Title>
         <Value>MTR_RD</Value>
         <Options>..\gams\pol_input\*.gms</Options>
         <range>0</range>
         <gamsName>result_type</gamsName>
         <tasks>Baseline calibration market model,
                Baseline calibration supply models,
                HSMU baseline,
                Run scenario with market model,Generate expost results
                Run scenario without market model,
                Run scenario only with market model
                Downscale scenario results
         </tasks>
         <tooltip>Name of the scenario file to run. The results will be stored under the name as well.</tooltip>
</control>
```

Output to GAMS:



```
$SETGLOBAL scenDes cge_rd_noChg
```

fileselDir

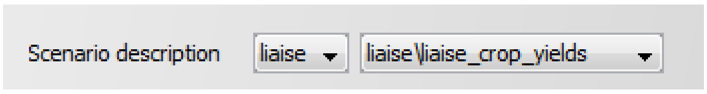
Purpose

Used for 1 of n selections of a list of files, potentially from sub-directories. That is e.g. interesting when the user can chose from a list of pre-existing scenario definitions in GAMS files.

Applicable fields:

Title, GamsName, Value, Options, Tasks, Style

Control optic:



Note: Drop down lists will appear if the user clicks on arrow.

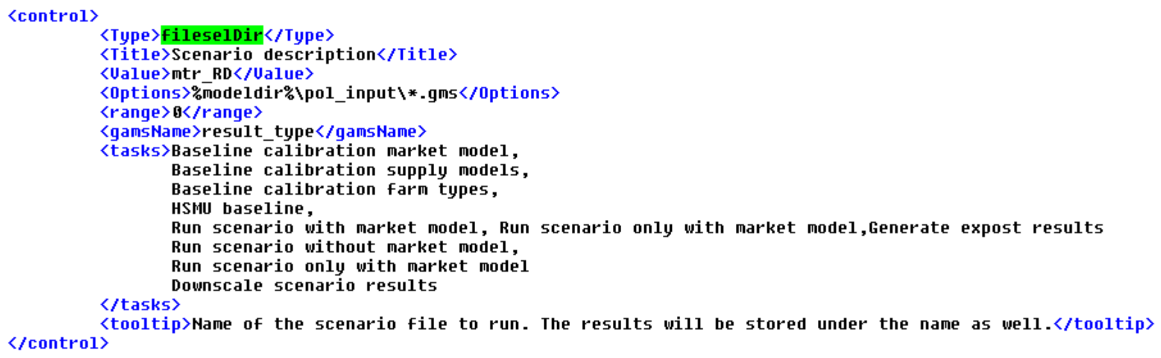
Possible value:

Defined by the file selection string in options field, .e.g ..\\gams\\pol_input\\cge_*.gms. The file extension fill be automatically removed from the items.

User action:

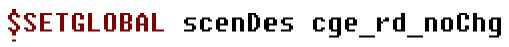
tick / untick one of the selection possibilities with mouse

Example definition:



```
<control>
        <Type>fileselDir</Type>
        <Title>Scenario description</Title>
        <Value>mtr_RD</Value>
        <Options>%modeldir%\pol_input\*.gms</Options>
        <range>0</range>
        <gamsName>result_type</gamsName>
        <tasks>Baseline calibration market model,
               Baseline calibration supply models,
               Baseline calibration farm types,
               HSMU baseline,
               Run scenario with market model, Run scenario only with market model,Generate expost results
               Run scenario without market model,
               Run scenario only with market model
               Downscale scenario results
        </tasks>
        <tooltip>Name of the scenario file to run. The results will be stored under the name as well.</tooltip>
</control>
```

Output to GAMS:



```
$SETGLOBAL scenDes cge_rd_noChg
```

Multilist / MultiListNonZero

Purpose

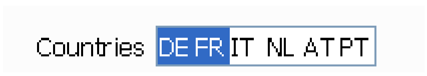
Used for m of n selections, i.e. in cases where features are not mutually exclusive.

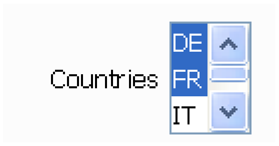
Multilist allows m = 0, i.e. also empty selection. MultiListNonZero requires m > 0, i.e. at least one element must be selected.

Applicable fields:

Title, GamsName, Value, Options, range, Tasks, Style

Control optic:





Notes:

- left hand side: range=0   right hand side: range = 3
- Drop down list will appear if the user clicks on arrow, and number of elements > range and range<>0

Possible value:

Defined by options field

User action:

tick / untick box fields in the control with mouse

Example definition:

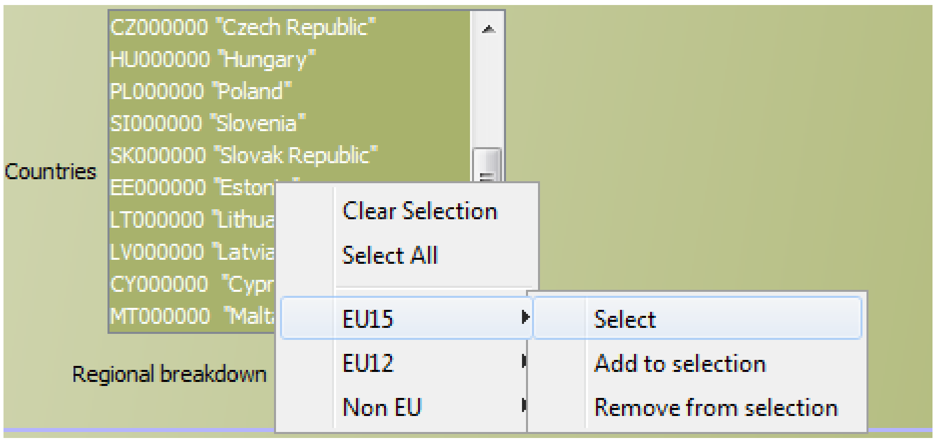
```
<control>
         <order>1426</order>
         <Type>multilist</Type>
         <Title>Longrun Option</Title>
         <Options>FAO2050 "Fao projections"
                  GLOBIOM_EU "Projections with GLOBIO EU model"
                  GLOBIOM_GL "Projections with global GLOBIOM model"
         </Options>
         <Value>FAO2050 "Fao projections"</Value>
         <range>3</range>
         <gamsName>longrunScen</gamsName>
         <tasks>Build global database</tasks>
</control>
```

Output to GAMS:

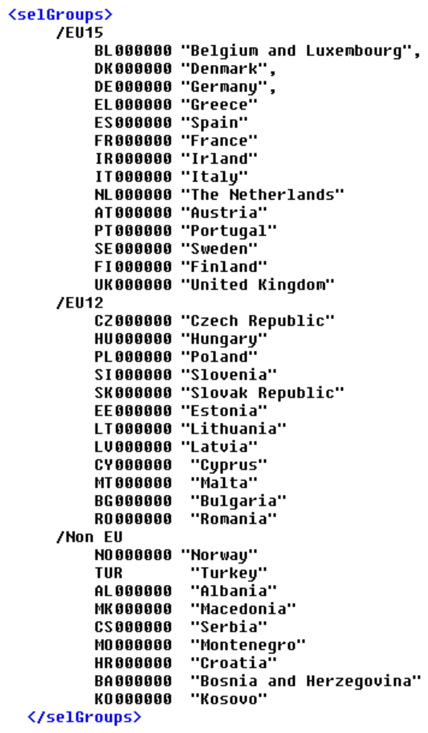
```
SET  Countries /
DE
FR
/;
```

Selection groups

The *multilist* control features a pop-up menu which without selection groups only allows to clear the selection or to select all items (see below).



The control definition files can define selection groups which allow for groups of items to be selected, added or removed from the selection. Each selection group starts with a forward slash "/" following by the name of the group. The items are and the next selection group are then comma separated as shown below. Commas can be skipped if the next item is on a different line.



```
<selGroups>
     /EU15
         BL000000 "Belgium and Luxembourg",
         DK000000 "Denmark",
         DE000000 "Germany",
         EL000000 "Greece"
         ES000000 "Spain"
         FR000000 "France"
         IR000000 "Irland"
         IT000000 "Italy"
         NL000000 "The Netherlands"
         AT000000 "Austria"
         PT000000 "Portugal"
         SE000000 "Sweden"
         FI000000 "Finland"
         UK000000 "United Kingdom"
     /EU12
         CZ000000 "Czech Republic"
         HU000000 "Hungary"
         PL000000 "Poland"
         SI000000 "Slovenia"
         SK000000 "Slovak Republic"
         EE000000 "Estonia"
         LT000000 "Lithuania"
         LV000000 "Latvia"
         CY000000  "Cyprus"
         MT000000  "Malta"
         BG000000  "Bulgaria"
         RO000000  "Romania"
     /Non EU
         NO000000 "Norway"
         TUR       "Turkey"
         AL000000  "Albania"
         MK000000  "Macedonia"
         CS000000  "Serbia"
         MO000000  "Montenegro"
         HR000000  "Croatia"
         BA000000  "Bosnia and Herzegovina"
         KO000000  "Kosovo"
  </selGroups>
```

Radiobuttons

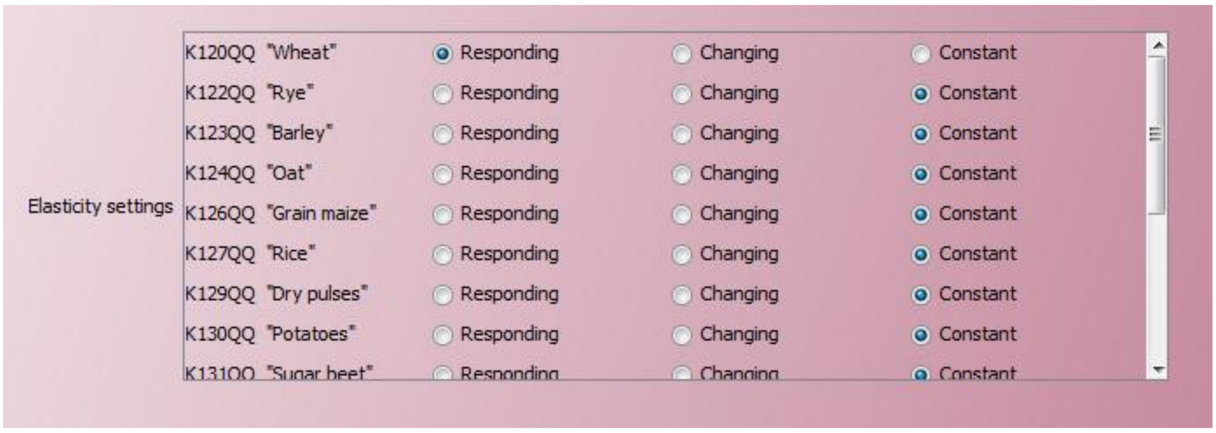
Purpose

Used to select for several items a one of n-settings, outputted as two-dimensional set

Applicable fields:

Title, GamsName, Value, Options, Rows, Tasks, Style

Control optic:



Elasticity settings

K120QQ "Wheat"	[✓ Responding]	Changing	Constant
K122QQ "Rye"	Responding	Changing	[✓ Constant]
K123QQ "Barley"	Responding	Changing	[✓ Constant]
K124QQ "Oat"	Responding	Changing	[✓ Constant]
K126QQ "Grain maize"	Responding	Changing	[✓ Constant]
K127QQ "Rice"	Responding	Changing	[✓ Constant]
K129QQ "Dry pulses"	Responding	Changing	[✓ Constant]
K130QQ "Potatoes"	Responding	Changing	[✓ Constant]
K131QQ "Sugar beet"	Responding	Changing	[✓ Constant]

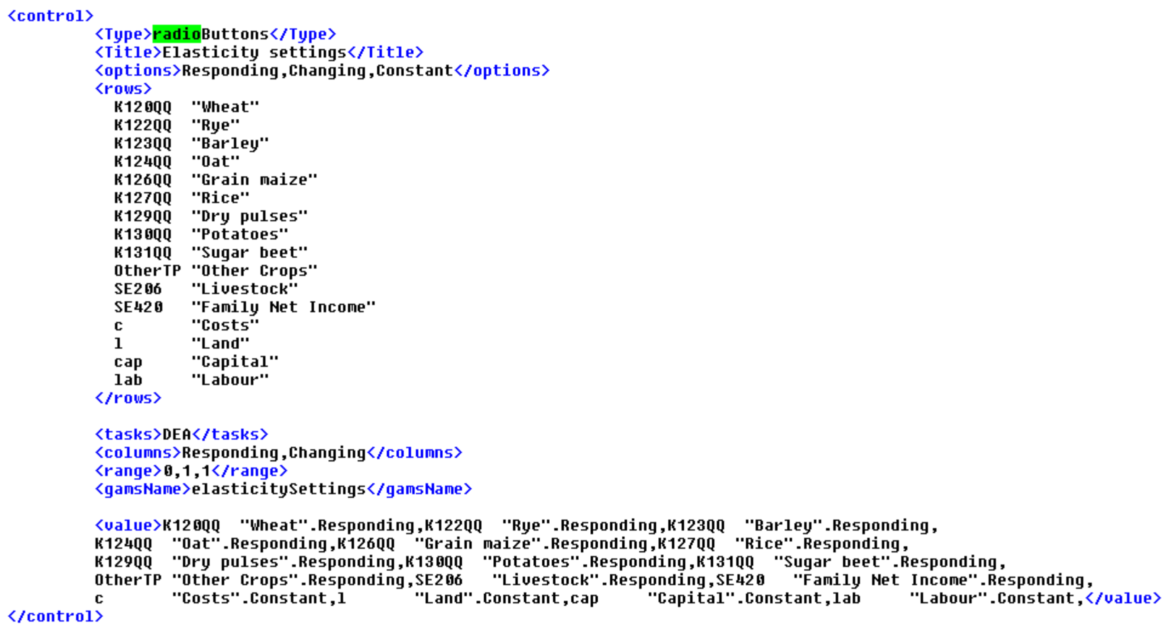
Possible values:

Defined by range field

User action:

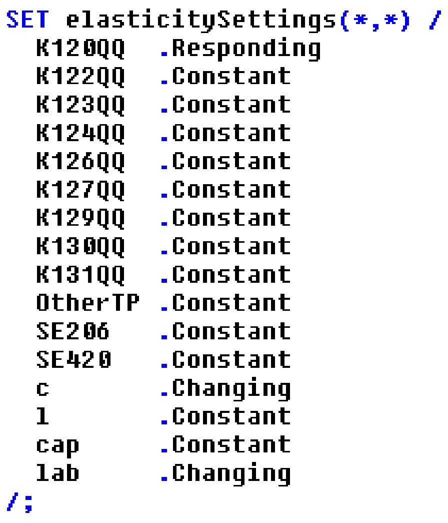
Select value by pressing up/down arrows or by editing the field with keyboard

Example definition:



```
<control>
        <Type>radioButtons</Type>
        <Title>Elasticity settings</Title>
        <options>Responding,Changing,Constant</options>
        <rows>
          K120QQ  "Wheat"
          K122QQ  "Rye"
          K123QQ  "Barley"
          K124QQ  "Oat"
          K126QQ  "Grain maize"
          K127QQ  "Rice"
          K129QQ  "Dry pulses"
          K130QQ  "Potatoes"
          K131QQ  "Sugar beet"
          OtherTP "Other Crops"
          SE206   "Livestock"
          SE420   "Family Net Income"
          c       "Costs"
          l       "Land"
          cap     "Capital"
          lab     "Labour"
        </rows>

        <tasks>DEA</tasks>
        <columns>Responding,Changing</columns>
        <range>0,1,1</range>
        <gamsName>elasticitySettings</gamsName>

        <value>K120QQ  "Wheat".Responding,K122QQ  "Rye".Responding,K123QQ  "Barley".Responding,
        K124QQ  "Oat".Responding,K126QQ  "Grain maize".Responding,K127QQ  "Rice".Responding,
        K129QQ  "Dry pulses".Responding,K130QQ  "Potatoes".Responding,K131QQ  "Sugar beet".Responding,
        OtherTP "Other Crops".Responding,SE206   "Livestock".Responding,SE420   "Family Net Income".Responding,
        c       "Costs".Constant,l       "Land".Constant,cap     "Capital".Constant,lab     "Labour".Constant,</value>
</control>
```

Output to GAMS:



```
SET elasticitySettings(*,*) /
  K120QQ  .Responding
  K122QQ  .Constant
  K123QQ  .Constant
  K124QQ  .Constant
  K126QQ  .Constant
  K127QQ  .Constant
  K129QQ  .Constant
  K130QQ  .Constant
  K131QQ  .Constant
  OtherTP .Constant
  SE206   .Constant
  SE420   .Constant
  c       .Changing
  l       .Constant
  cap     .Constant
  lab     .Changing
/;
```

Slider

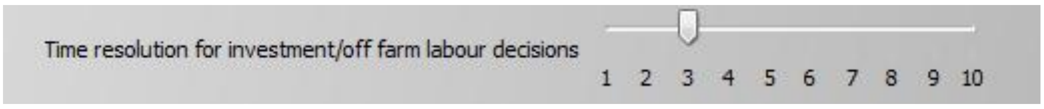
Purpose

Used to select one integer value from a given range of allowed ones. The increments must also be defined.

Applicable fields:

Title, GamsName, Value, Options, range, Tasks, Style

Control optic:



Note: Selectable values will be restricted according to the increment definition.

Possible values:

Defined by range field

User action:

Select value by pressing up/down arrows or by editing the field with keyboard

Example definition:

```
<control>
         <Type>slider</Type>
         <Title>Time resolution for investment/off farm labour decisions</Title>
         <Value>3.0</Value>
         <range>1,10,1</range>
         <gamsName>timeResolutionInv</gamsName>
         <tasks>all</tasks>
</control>
```

Output to GAMS:

```
$SETGLOBAL Set_substitution_elasticty 5
```

Spinner

Purpose

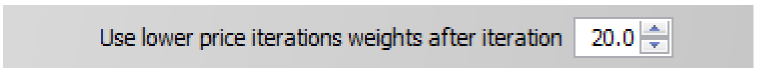
Used to select a integer value from a range of allowed ones. The increment is always unity. Could be internally used as a floating value, e.g. by using it for shares in percentages terms.

If the range of the spinner is large, it might be hard for the user to pick a specific value. In that case, a spinner is easier to control.

Applicable fields:

Title, GamsName, Value, Options, range, Tasks, Style

Control optic:



Possible value:

Defined by range field

User action:

Select value by moving slider

Example definition:

```
  <control>
          <order>1011</order>
          <Type>spinner</Type>
          <Title>min end year of planning horizon</Title>
          <Value>2020</Value>
          <range>2015,2100,1,15</range>
          <gamsName>lastYearMin</gamsName>
          <tasks>Experiments</tasks>
 </control>
```

Output to GAMS:

```
$SETGLOBAL Relative_weight_flows 20
```

Table / TableSimple

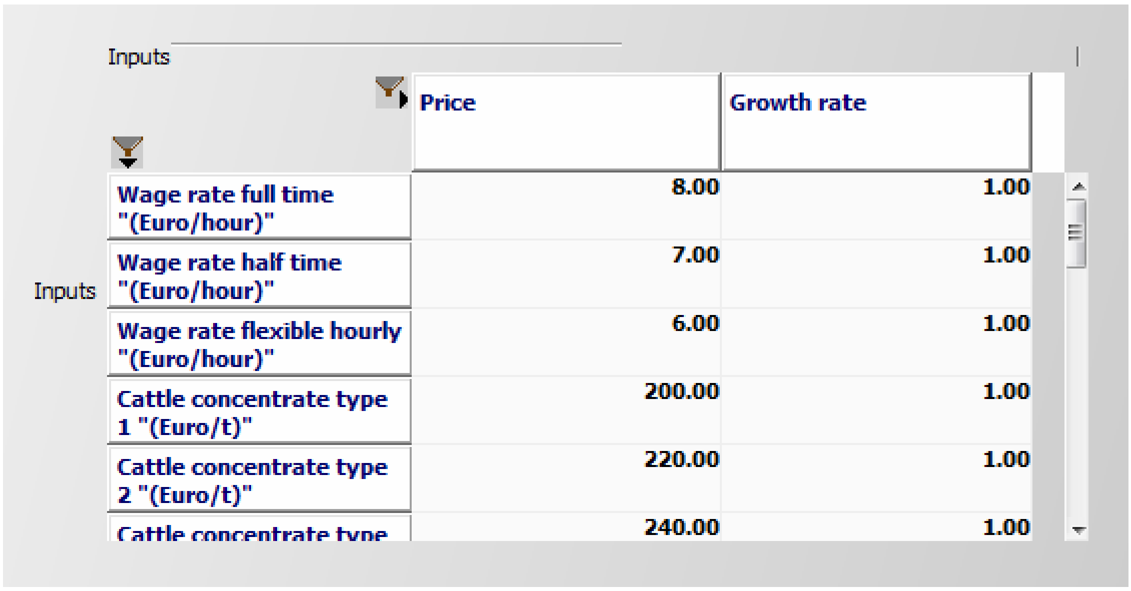
Purpose

Define a table with floating point values passed to GAMS.

Applicable fields:

Title, GamsName, Value, Columns, Rows, Dim3s, Range, Tasks, Style

Control optic:



	Price	Growth rate
Wage rate full time "(Euro/hour)"	8.00	1.00
Wage rate half time "(Euro/hour)"	7.00	1.00
Wage rate flexible hourly "(Euro/hour)"	6.00	1.00
Cattle concentrate type 1 "(Euro/t)"	200.00	1.00
Cattle concentrate type 2 "(Euro/t)"	220.00	1.00
Cattle concentrate type	240.00	1.00

User action:

- *Edit single fields with numerical values. Cut/Paste via clipboard possible*

Example definition:

```
<control>
         <order>3110</order>
         <Type>table</Type>
         <Title>Trade elasticities</Title>
         <Value>0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,
               -0.5,-0.5,-0.5,-0.5,-0.5,-0.5,-0.5,-0.5,-0.5,-0.5,-0.5,-0.5
         </Value>
         <Columns>Import supply,Export demand</Columns>
         <Rows>AGR "Agriculture"
               FOR "Forestry"
               OPP "Other primary sectors"
               FOP "Food Processing"
               MAN "Manufacturing"
               ENE "Energy"
               CNS "Construction"
               TTR "Trade and Transport"
               HOT "Hotel and restaurants"
               EDU "Education"
               OSE "Other services"</Rows>
         <range>0.1,5.0,0.1,-5.0,-0.1,0.1,</range>
         <gamsName>p_tradeElas</gamsName>
         <tasks>Calibrate CGE</tasks>
</control>
```

Notes:

- The range field might comprise several tuples of “low-up-increment” which will then be assigned to the columns of the tables. If there is only one tuple, it will be used for all columns.
- If a range is given, a spinner will be used as the cell editor and values outside the range will be rejected.

Output to GAMS:

```
 PARAMETER p_tradeElas/
'test1'.'AGR "Agriculture"'.'Import supply' 0.5
'test1'.'FOR "Forestry"'.'Import supply' 0.5
'test1'.'OPP "Other primary sectors"'.'Import supply' 0.5
'test1'.'FOP "Food Processing"'.'Import supply' 0.5
'test1'.'MAN "Manufacturing"'.'Import supply' 0.5
'test1'.'ENE "Energy"'.'Import supply' 0.5
'test1'.'CNS "Construction"'.'Import supply' 0.5
'test1'.'TTR "Trade and Transport"'.'Import supply' 0.5
'test1'.'HOT "Hotel and restaurants"'.'Import supply' 0.5
'test1'.'EDU "Education"'.'Import supply' 0.5
'test1'.'OSE "Other services"'.'Import supply' 0.5
'test2'.'AGR "Agriculture"'.'Import supply' -0.5
'test2'.'FOR "Forestry"'.'Import supply' -0.5
'test2'.'OPP "Other primary sectors"'.'Import supply' -0.5
'test2'.'FOP "Food Processing"'.'Import supply' -0.5
'test2'.'MAN "Manufacturing"'.'Import supply' -0.5
'test2'.'ENE "Energy"'.'Import supply' -0.5
'test2'.'CNS "Construction"'.'Import supply' -0.5
'test2'.'TTR "Trade and Transport"'.'Import supply' -0.5
'test2'.'HOT "Hotel and restaurants"'.'Import supply' -0.5
'test2'.'EDU "Education"'.'Import supply' -0.5
'test2'.'OSE "Other services"'.'Import supply' -0.5
'test1'.'AGR "Agriculture"'.'Export demand' 0.0
'test1'.'FOR "Forestry"'.'Export demand' 0.0
'test1'.'OPP "Other primary sectors"'.'Export demand' 0.0
'test1'.'FOP "Food Processing"'.'Export demand' 0.0
'test1'.'MAN "Manufacturing"'.'Export demand' 0.0
'test1'.'ENE "Energy"'.'Export demand' 0.0
'test1'.'CNS "Construction"'.'Export demand' 0.0
'test1'.'TTR "Trade and Transport"'.'Export demand' 0.0
'test1'.'HOT "Hotel and restaurants"'.'Export demand' 0.0
'test1'.'EDU "Education"'.'Export demand' 0.0
'test1'.'OSE "Other services"'.'Export demand' 0.0
'test2'.'AGR "Agriculture"'.'Export demand' 0.0
'test2'.'FOR "Forestry"'.'Export demand' 0.0
'test2'.'OPP "Other primary sectors"'.'Export demand' 0.0
'test2'.'FOP "Food Processing"'.'Export demand' 0.0
'test2'.'MAN "Manufacturing"'.'Export demand' 0.0
'test2'.'ENE "Energy"'.'Export demand' 0.0
'test2'.'CNS "Construction"'.'Export demand' 0.0
'test2'.'TTR "Trade and Transport"'.'Export demand' 0.0
'test2'.'HOT "Hotel and restaurants"'.'Export demand' 0.0
'test2'.'EDU "Education"'.'Export demand' 0.0
'test2'.'OSE "Other services"'.'Export demand' 0.0
 /;
```

Style options

Most of the controls allow for a style tag. Currently, only the following two options are supported:

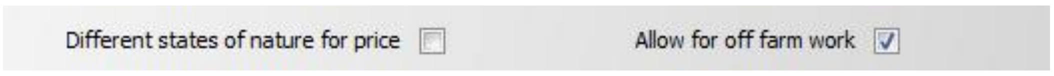
1. Left alignment

```
<control>
         <Type>singlelist</Type>
         <Title>Base year</Title>
         <Value>2004</Value>
         <Options>2004,2006,2008</Options>
         <gamsName>BaseYear</gamsName>
         <style>vAlignment:left</style>
         <tasks>Define fts from FSS,
---------------------------------------------------------------------------------------------
         </tasks>
</control>
```

2. Putting the control in the same line below the last one

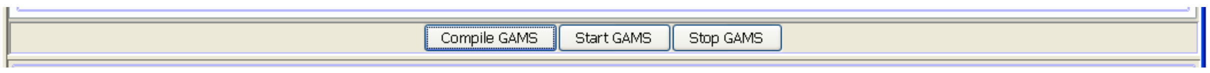
```
<control>
         <Type>checkbox</Type>
         <Title>Allow for off farm work</Title>
         <Value>true</Value>
         <style>sameLine:true</style>
         <gamsName>allowForOffFarm</gamsName>
         <tasks>Single farm run, Calculate MACs, Experiments dairy,Experiments arable</tasks>
</control>
```

Which leads to the following:

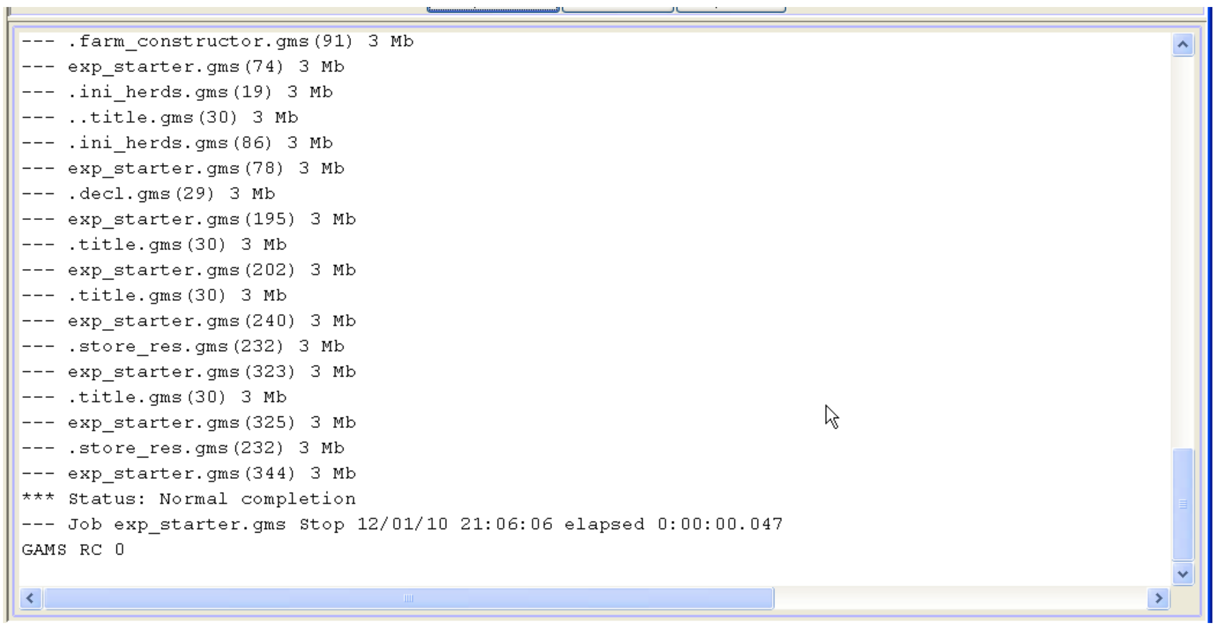


Starting GAMS from GGIG

GGIG allows starting the GAMS project directly from the interface, either in compile or run mode. A break request can also be sent to GAMS ("stop GAMS"):

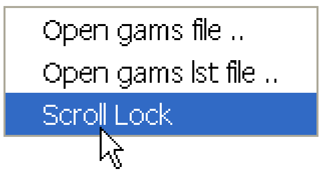


Once started, the GAMS project routes its output to the console back to lower right part of the interface:



```
--- .farm_constructor.gms(91) 3 Mb
--- exp_starter.gms(74) 3 Mb
--- .ini_herds.gms(19) 3 Mb
--- ..title.gms(30) 3 Mb
--- .ini_herds.gms(86) 3 Mb
--- exp_starter.gms(78) 3 Mb
--- .decl.gms(29) 3 Mb
--- exp_starter.gms(195) 3 Mb
--- .title.gms(30) 3 Mb
--- exp_starter.gms(202) 3 Mb
--- .title.gms(30) 3 Mb
--- exp_starter.gms(240) 3 Mb
--- .store_res.gms(232) 3 Mb
--- exp_starter.gms(323) 3 Mb
--- .title.gms(30) 3 Mb
--- exp_starter.gms(325) 3 Mb
--- .store_res.gms(232) 3 Mb
--- exp_starter.gms(344) 3 Mb
*** Status: Normal completion
--- Job exp_starter.gms Stop 12/01/10 21:06:06 elapsed 0:00:00.047
GAMS RC 0
```

The pane with the content can be scrolled by a right mouse click in the pane to open a popup menu. If an editor is added under “opther options”, the GAMS and the listing file can be opened as well:

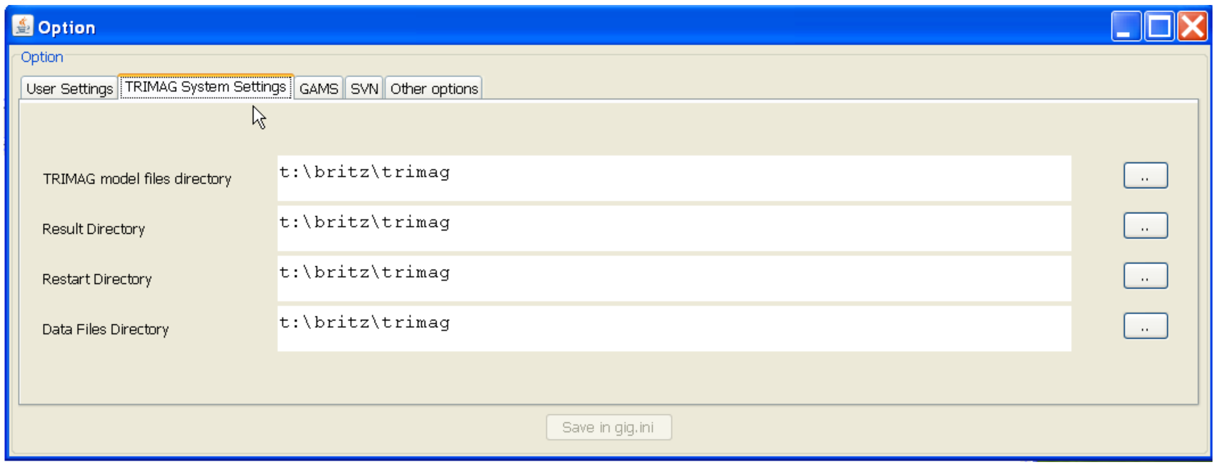


The pane can hence be “frozen” so that e.g. the status of a model solve can be inspected while the project continues to run. In order to successfully start a project, the ini file for GGIG must comprise the information where the GAMS executable can be found, but also where the GAMS code of the project to start is stored.

General interface settings

The interface has a few standard settings which can also be accessed via the “edit settings dialogue”. These are:

- **Certain file locations**: the directory where GDX files for results are assumed to be stored (resDir), and three directories which can be used to adjust the specific model application: the root of the GAMS file (workDir in GAMS), called modelDir, a directory for restart files and one for data files.



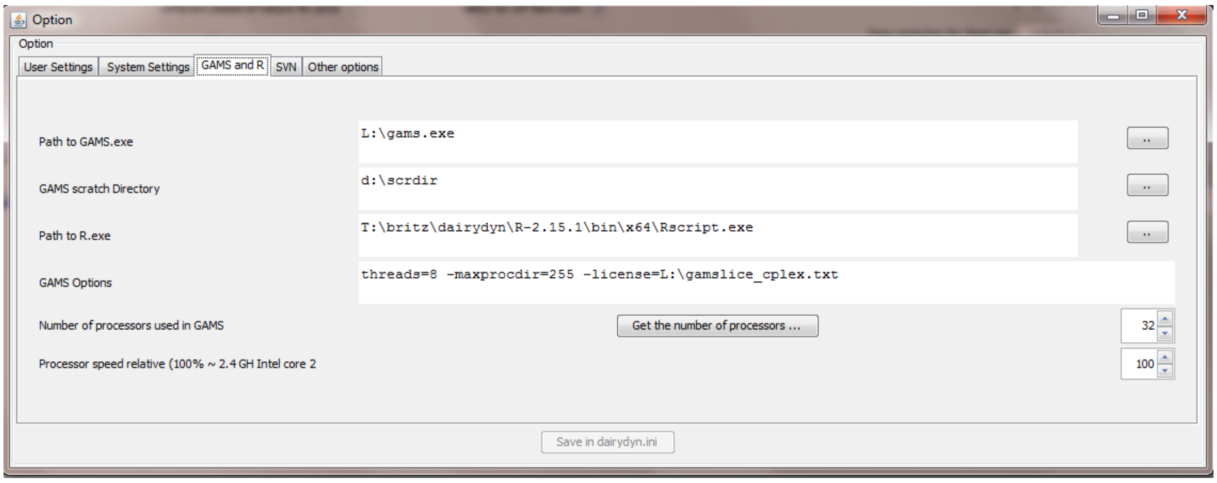
TRIMAG model files directory t:\britz\trimag
Result Directory t:\britz\trimag
Restart Directory t:\britz\trimag
Data Files Directory t:\britz\trimag

Note: The name of the system (here TRIMAG) is defined in the „GGIG.INI“ file

Default settings can be defined in the XML file:

```
<datDir><attr>..\dat</attr></datDir>
<modelDir><attr>..\gams</attr></modelDir>
<resDir><attr>..\results</attr></resDir>
<restartDir><attr>..\restart</attr></restartDir>
```

GAMS and R related settings

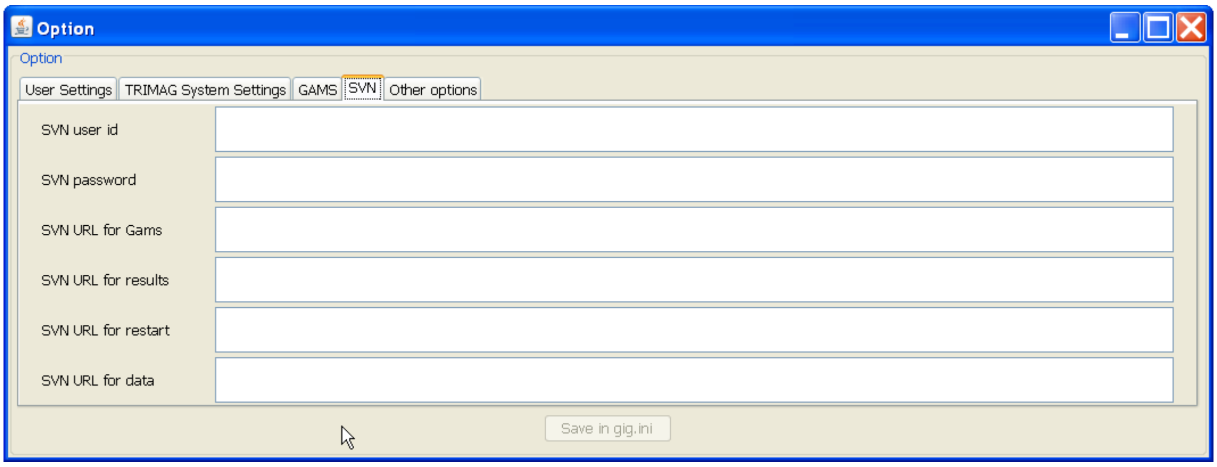


Path to GAMS.exe L:\gams.exe
GAMS scratch Directory d:\scrdir
Path to R.exe T:\britz\dairydyn\R-2.15.1\bin\x64\Rscript.exe
GAMS Options threads=8 -maxprocdir=255 -license=L:\gamslice_cplex.txt
Number of processors used in GAMS 32
Processor speed relative (100% ~ 2.4 GH Intel core 2 100

These settings can also be defined in the XML file:

```
<gamsexe><attr>D:\gams23.7\gams.exe</attr></gamsexe>
<rexe><attr>D:\r\bin\64\r.exe</attr></rexe>
<gamsoptions><attr>threads 0</attr></gamsoptions>
<numberofprocessors><attr>8</attr></numberofprocessors>
<processorSpeedRelative><attr>100</attr></processorSpeedRelative>
<scratchDir><attr>100</attr></scratchDir>
```

SVN related settings



SVN user id
SVN password
SVN URL for Gams
SVN URL for results
SVN URL for restart
SVN URL for data

The SVN settings can be used to perform checkout and updates in cases where the model code with related data, restart files or result files is under versioning control on a SVN server. If the model is not under version control, the settings “svn=no” renders the tabbed plan invisible.

Default settings can be defined in the XML file:

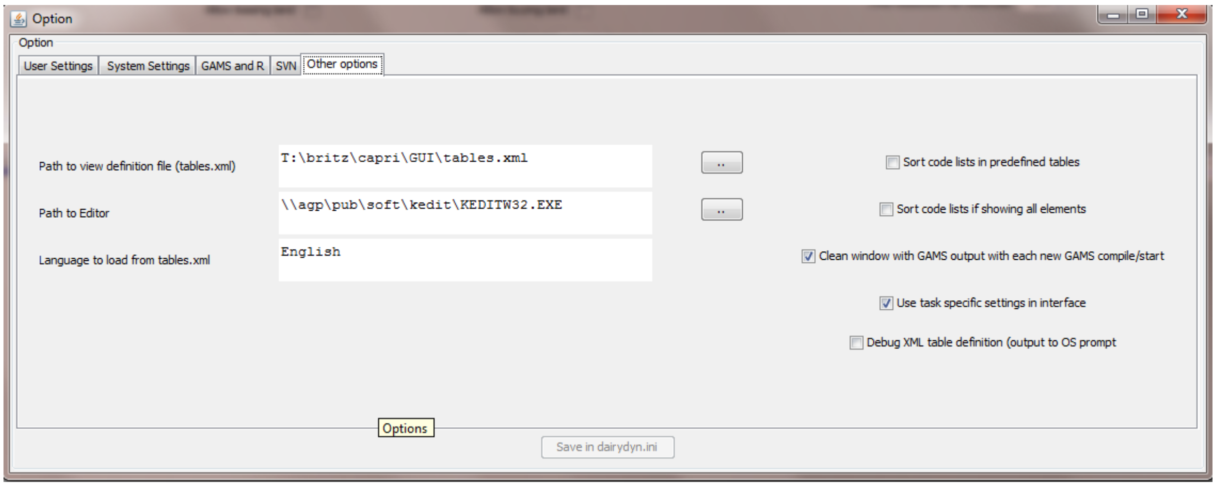
```
<SvnURLforDat><attr></attr></SvnURLforDat>
<SvnURLforGUI><attr>https://svn1.agp.uni-bonn.de/svn/capri/trunk/GUI</attr></SvnURLforGUI>
<SvnURLforGams><attr>https://svn1.agp.uni-bonn.de/svn/capri/trunk/gams</attr></SvnURLforGams>
<SvnURLforRestart><attr></attr></SvnURLforRestart>
<SvnURLforResult><attr>https://svn1.agp.uni-bonn.de/svn/capri/trunk/results/regcge</attr></SvnURLforResult>
```

Including credentials:

```
<SVNPwd><attr>1+\^.]</attr></SVNPwd>
<SVNUserID><attr>ierdlag_</attr></SVNUserID>
```

The credentials are obfuscated. In order to edit them, use the dialogue and copy the settings from the generated ini file to the XML.

Settings linked to the exploitation tools



Path to view definition file (tables.xml) T:\britz\capri\GUI\tables.xml

Path to Editor \\agp\pub\soft\kedit\KEDITW32.EXE

Language to load from tables.xml English

☐ Sort code lists in predefined tables

☐ Sort code lists if showing all elements

☑ Clean window with GAMS output with each new GAMS compile/start

☑ Use task specific settings in interface

☐ Debug XML table definition (output to OS prompt

The standard table file can be defined in the XML:

```
<xmlTables><attr>tables.xml</attr></xmlTables>
```

Meta data handling

Why meta data?

Meta data are data about data. In many GAMS projects, it is impossible or cumbersome to tell exactly based on which shocks and settings results of a model run had been generated. That is due to the fact that run specific settings are not stored at all or not stored together stored with the results of the run. Later on, result users are often left guessing what exactly the settings underlying the run might have been.

In order to overcome that problem, the GGIG, drawing on CAPRI GUI concepts, passes all interface settings, plus the user name and the current time, forward to GAMS in one SET called META.

A correctly defined interface with GGIG should allow to steer *all* run specific settings. If that is the case, the meta data generated by GGIG will provide an exact and sufficient definition of all run specific inputs, ensuring that all relevant meta data about a run are stored along with quantitative results in the same GDX file. Accordingly, GDX files shipped to other desks or committed e.g. to a SVN server still carry all necessary information to identify exactly the run.

Technical concept

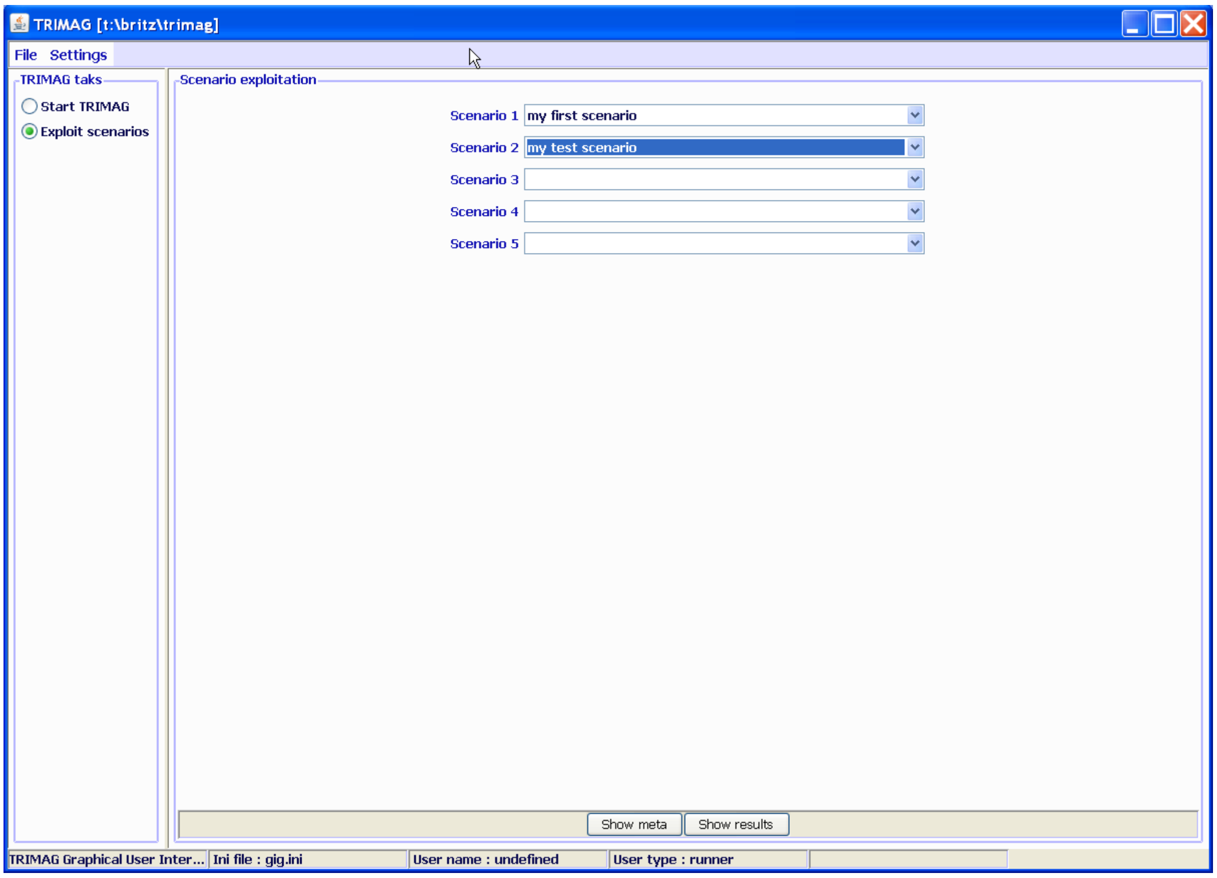
The meta handling is straight forward. The state of the different control is mapped into pairs of set elements and related long text descriptions as shown below from an example application:

```
SET META /
'Scenario description' 'my test scenario'
'Choose model type' 'CGE'
'Relative weight flows' '30'
'Use demand elasticities' 'true'
'Set substitution elasticty' '6.0'
'Countries' 'NL,'
 /;
```

and, might with one GAMS statement as shown below, stored in the GDX files along with the results:

```
execute_unload "%scenario_description%.gdx" META,RESULT;
```

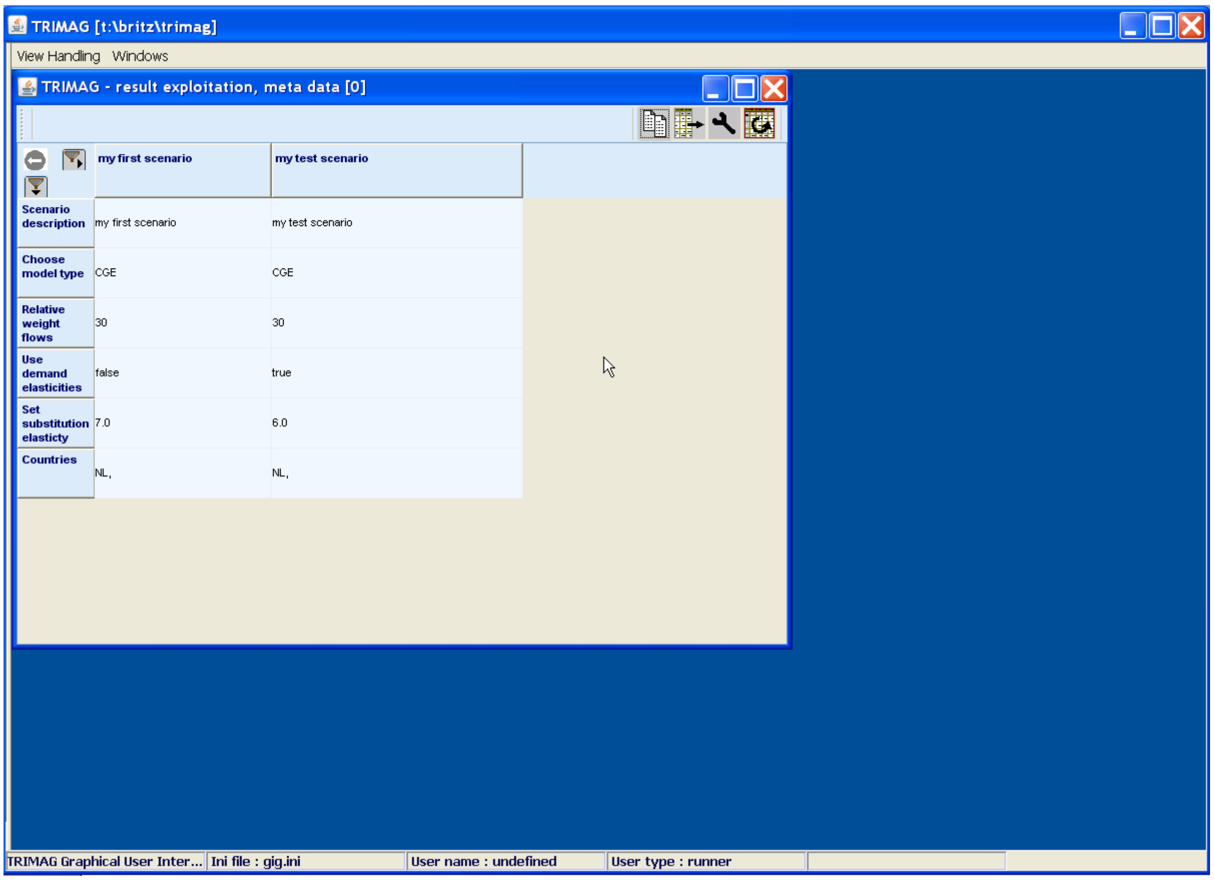
The user might then select some scenario:



Scenario 1: my first scenario
Scenario 2: my test scenario
Scenario 3:
Scenario 4:
Scenario 5:

TRIMAG Graphical User Inter... | Ini file : gig.ini | User name : undefined | User type : runner

And then, by pressing “show meta”, view the settings used for these scenarios:



	my first scenario	my test scenario
Scenario description	my first scenario	my test scenario
Choose model type	CGE	CGE
Relative weight flows	30	30
Use demand elasticities	false	true
Set substitution elasticty	7.0	6.0
Countries	NL,	NL,

TRIMAG Graphical User Inter... | Ini file : gig.ini | User name : undefined | User type : runner

Exploitation

The basic strategy of the GGIG exploitation tools roots in the CAPRI exploitation tools, which require that all model results are stored on an up to 10 dimensional cube, which is then stored in a GDX as a sparse matrix. Additional dimension can be added if several files are loaded, e.g. to compare scenarios or years. A specific XML dialect defines views (filters, pivots, view types) into the cube, and allows the user to load several result sets – typically from different scenarios – in parallel.

If no table definition file is present, GIGG offers a GDX viewer which some interesting possibilities not found in the standard GDX viewer (such as numerical sorting, statistics, selections). For details, the CAPRI GUI user manual should be consulted.

The software behind the mapping viewer and the CAPRI exploitation tools

Reading the following chapter is not necessary to work with the GUI, but rather intended for a reader who is technically interested. The original software implementation of CAPRI was based on software available at ILR at that time and comprised a DBMS realized in

FORTRAN with C/C++ code for the GUI. The very first maps in CAPRI (in 1998) were produced with an MS-EXCEL mapping plug-in which was at that time a cost-free add-on. However, moving the data to EXCEL and then loading them in the viewer was not a real option for the daily debugging work on the data base and the model. Therefore, shortly before the first CAPRI project ended in 1999, a JAVA applet was programmed by W. Britz which was able to draw simple maps from CSV-Files, automatically produced by the CAPMOD GAMS code. That code with slight modification remained active for quite a while, and some of the features are still to be found in the current mapping viewer. Then for a while, the exploitation tools were based on XML/XSLT+SVG and a mapping viewer in SVG was realized. However, the XML solution had the big disadvantage of requiring a large amount of single ASCII input files, and was not really performant when complex pivoting was used.

Therefore, the next evolution step was a pure Java GUI with direct access to GDX files which is the current state of the art in CAPRI. GDX files are an internal file format used by GAMS which allows a rather efficient I/O for large sparse tables. An API library allows to access GDX files from other applications. That design has the obvious advantage to be firstly based onto the portable JAVA language. Secondly, as no external DBMS is used, it is possible to use CAPRI by solely executing GAMS programs. CAPRI might hence run on any system supported by GAMS, without the need to install additional software.

The GUI consists of three rather independent components. Firstly, a GUI to control the different work steps of CAPRI. The code deals mostly with defining GUI controls (button, scroll-down lists etc.) to manipulate properties of CAPRI tasks, and then to start them as GAMS processes. That part has been thoroughly refactored with the revision of 2008. A second important part is the CAPRI exploitation tool, which are basically generic enough to be used for other modeling systems as well. The current refactoring left most of the code untouched compared to the code developed since 2006, with the exemption of the graphics which is now based on the JFreeChart library. However, as discussed below, in 2007, the mapping viewer was refactored in larger part to host the 1x1 km grid solution developed in the CAPRI-Dynaspat project. The exploitation tool is a rather unique solution to exploit result sets from economic models based on the definitions of views which are defined in XML tables. It combines features from DBMS reporting, data mining, spreadsheet functionalities and GIS into one package. And thirdly, there are some specialized pieces as the HTML based GAMS documentation generator which are linked into the GUI.

CAPRI tasks as business model

A core concept in the new layout is a business object called *AgpTask*. Technically defined as an interface, such an object represents a work task in the overall CAPRI system such a run of CAPREG to build the regional data base. The interface requires getters and setters for properties such as *baseYear*, *simYear or MemberStates*. The setters can be accessed either by a GUI interface or by the batch execution facility, formally by a class implementing the interface *AgpTaskHandler*.

Most tasks are GAMS executable tasks according to their *isGams* property. These tasks also provide access to the name of the related GAMS program via *getGamsProgramName*. Each of these tasks has also a method called *generateIncludeFile* which generates the specific so-called include file in GAMS format for that task.

The objects also know about the main GDX file they are generating via *getGdxResultFiles*. Related to that, they allow setting the logical names of the data dimension in the result data set via *setDimNames* and *setXMLTablesDims*.

Once the properties of a task had been defined, their logical consistency can be checked by invoking the method *checkSettings*. Check settings returns a string with a description of the first error encountered.

That layout eases dramatically the update process of CAPRI. Definition of new tasks or changes to existing ones will generally not require changes in the GUI, but simply creates the necessity of either implementing a new object with the required methods or updating an existing one.

Execution of tasks via a GamsStarter and GamsThread

Execution of tasks with the property *isGams* is handled by a *GamsStarter* object. An instance of *GamsStarter* lets the task write out the necessary include file(s) in GAMS format to generate a specific instance of the specific task (a simulation run for a specific scenario, simulation year, with the market model switched on or off …). A *GamsStarter* also knows about the working directory or other specific GAMS settings as the scratch directory. It may generate a pipe for the GAMS output to the console to show it in a GUI.

An *AgpTask* can be executed by a *GamsStarter* who will then create a *GamsThread*. A *GamsThread* extends the *SwingWorker* interface of Java so that it may communicate with the normal event queue of JVM. A *GamsThread* can be gracefully terminated by sending a

SIGNT signal to the GAMS process. That will let the GAMS execution stop at a specific point determined by the GAMS engine itself and start the finalisation handling of GAMS as well as the removal of intermediate files and directories.

Refactoring the mapping part

When the 1x1 km grid layer was added to CAPRI during the CAPRI-Dynaspat project it became obvious that the existing JAVA code to produce maps needed some revision, especially regarding the way the geometry was stored. In this context, the question of using an existing GIS independently from CAPRI or the use of existing GIS classes plugged-into the CAPRI GUI was raised again and some tests with open-source products were undertaken. A stand-alone GIS as the sole option was certainly the less appealing solution. Firstly, it would have required producing rather large intermediate files and would have left the user with the time-consuming and often error prone task of exporting and importing the data. Secondly, the user would need to switch between two different programs and GUI standards. And thirdly, all the usual problems with installing and maintaining additional software on a work station would occur. However, as indicated later, the GUI naturally allows passing data over to external applications and does hence not prevent the user from using a full-fledged GIS solution.

The main points taken into account during the search of a map viewing solution for CAPRI were: (1) possibility to import data from the CAPRI GUI efficiently, (2) user-friendliness, (3) performance and (4), in the case of plug-in libraries, expected realization and maintenance resource need, and naturally (5) license costs. It turned quickly that an ideal product was not available. Some of the products were not able to allow for the necessary link between newly imported tables with region codes and an existing geo-referenced geometry. Others had very complex user interfaces or produced run-time errors, took ages to draw the HSMU maps or were quite expensive. From the different options tested, the gvSIG (http://www.gvsig.com/index.php?idioma=en) freeware GIS seemed to be the only option, allowing the user to import data from a CSV – which must however be semi-colon delimited – and join one of the columns to a shapefile. At least the version installed at that time was however running not very stable.

In the end, it was decided to build on the existing code base and let Wolfgang Britz write the additional code “on demand”. The main advantage of that approach is the fact that the mapping view is transparently integrated in the CAPRI GUI, it is sufficient to switch from

"Table" to "Map" in a drop-down list to produce a colored map, and that user demands regarding additional functionality may be and had been added, taking into account the specific needs of the CAPRI network.

Compared to ArcGIS, where the EU27 HSMU geometry plus codes and centroids requires about 340 Mbytes, the CAPRI version requires about 27Mbytes solely. Reading in the CAPRI GUI is somewhat slower compared to ArcGIS due to unzip on demand. The actual drawing operation takes about the same time as in ArcGIS (about 11 second for the full data set). Classification in Java is typically faster.

Views as the basic concept

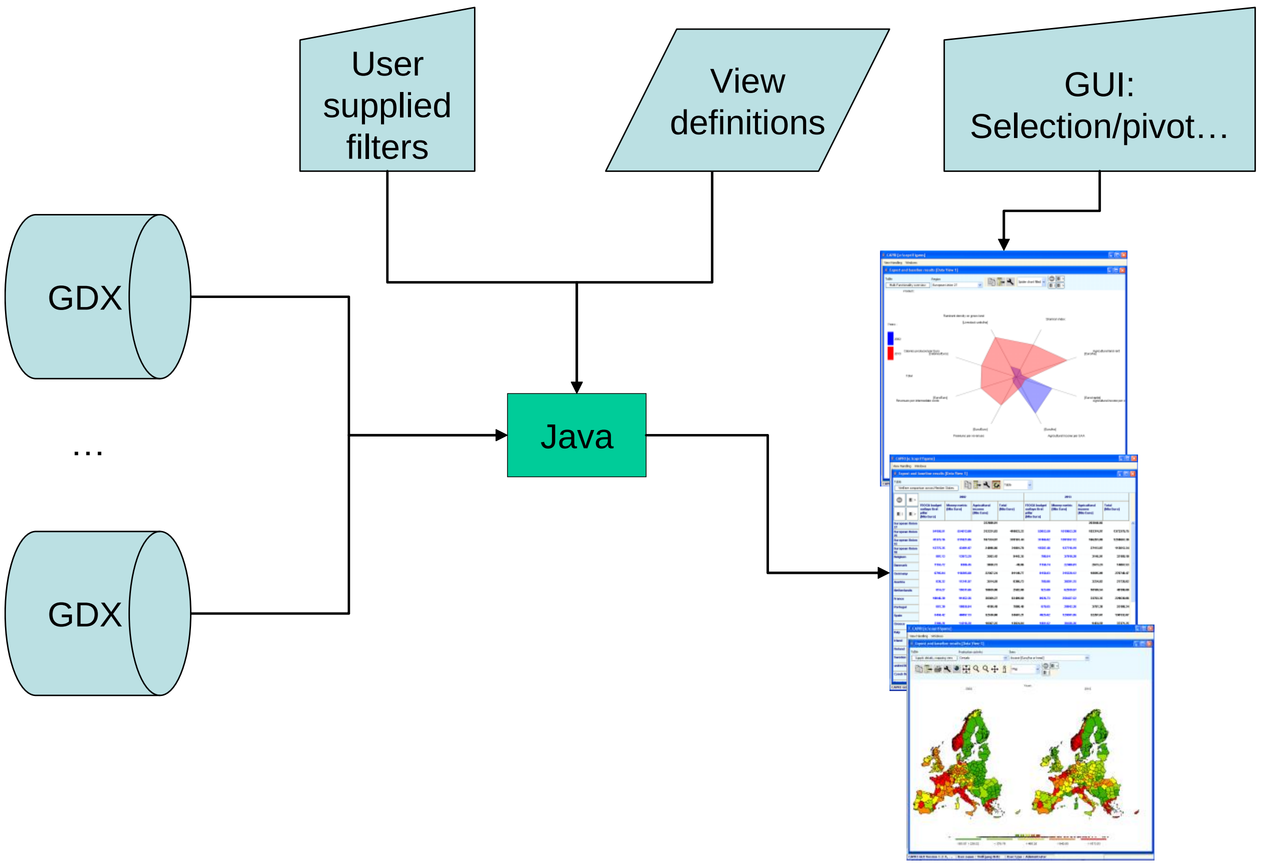
The concept of the CAPRI exploitation tools is centred on the idea of a view. Content wise, each view may be understood as showing one or several indicators relating to results of CAPRI working steps, e.g. environmental effects of farming, prices or market balances. Each view thus:

- extracts a certain collection of numerical values
- labels them so that they carry information to the user (long texts, units)
- chooses a matching presentation – as a table, map or graphic
- and arranges them in a suitable way on screen.

The views can be linked to each other, allowing a WEB like navigation through the data cube. Views can be grouped to themes. The user may open several views in parallel, and he may change the views interactively according to his needs, e.g. switch from a map to a tabular presentation, or change the pivot of the table, sort the rows etc.

Internally, each view is stored in an XML schema. Technically, a view can be understood as a combination of a pre-defined selection query, along with reporting information. The XML schema allows to attach long texts, units and tooltips to the items of a table, and thus to show meta-data information to the user. The XML schema hence replaces look up tables in a DBMS. It may equally store information regarding the pivoting, the view type (table, map, different graphic types), and for maps, classification, color ramp and number of classes. The views can be grouped into logical entities, and are shown as a popup menu to the user.

Tabular views may feature column and row groups. Empty columns and rows can be hidden; tables can be sorted by column, with multiple sort columns supported. Numerical filter can be applied to columns.



Data model

The underlying data model is very simple and straightforward. All data are kept in one large multi-dimensional data cube, and all values must either be float values or strings. Currently, only read-only is supported. Each data dimension is linked to a vector of string keys. Those keys are the base for the filter definitions. Currently, data cubes with up to six dimensions are used (regions – activities – items – trading partners – years – policy scenarios). The data storage model is equally optimised to the specific needs. As only float values or strings are supported, all data can be stored as one primitive array of either floats or strings. To allow fast and efficient indexing, a linear index is constructed from the multi-dimensional data cube, and the non-zero data and their indices are stored in a hash table. That renders data retrieval very fast. All data are loaded in memory at initialisation time: For moderately long linear indices about 10 Bytes are required to store a non-zero float and its index as an integer. If the maximal linear index is very large, the index is stored as a long and the storage need goes up to about 16 Bytes. For moderately sized data cubes, 20 Million numbers can hence be hosted in about 200 Mbytes.

The data are read from a generic file format generated by GAMS (General Algebraic Modelling System, a commonly used software package in economic modelling) called GDX, the software package on which CAPRI is based. Access to GDX is handled via an API provided by GAMS.

Client based solution

Technically, the exploitation tool is completely client based. That reflects the specific user profile of the CAPRI modelling system where the exploitation tool is integrated with an economic model and tools building up its data base. The main aim of the tool is to support forward looking policy analysis. For this purpose users will create their own scenarios and in some cases even own variants of the export data, which will lead to processes requiring considerable processing and storage resources. A client-server solution where the production process and data storage would need to be hosted on a web server is therefore not a preferred solution, also as users will often develop variants of the modelling system by code modification in GAMS, and contribute to its development. The structure of the data driver would however very easily support linkage to a network or WEB based data bases. It should however be noted that the data base and GAMS code are managed via a Software versioning system, which is a kind of client-server environment.

The geometry model

The mapping viewer of CAPRI is based on very simple and straightforward concepts. First of all, it basically supports solely polygon geometries not comprising holes, line strings (interpreted as rivers) and points for labelling. The storage model is optimised to host rectangles, and is especially efficient if the polygons vertexes are all points in a raster. The topology is not read from a shapefile, but stored in a generic rather simple format. However, a shapefile interface to generate the generic format is available. The vertices are stored in x,y coordinates, already projected in a rectangular coordinate system, and the viewer does not deal with the geographic coordinate system, but simply scales the rectangular coordinates in the viewport. The viewer in its current version solely supports one layer of quantities. Those restrictions naturally allow reducing memory needs, and, thanks to the rather simple data structures, also rather allow performing drawing operations. It should be noted that the JIT compiler of JAVA is indeed rather fast.

The biggest topology currently handled simultaneously covers an intersection of Corinne Land Cover, slope classes and Soil Morphological Units and comprises around 2.7 Million polygons for EU27. As the majority of the polygons are rectangles, not more then 6-7 Million points needed to be stored. The topology handler and the drawing routines separate rectangles, for which only the two outer points are stored, from polygons, for which the vertices and centroids are stored.

The viewer is written in Java. There are two variants. One is a stand-alone version of the viewer realised as an applet. It reads from an internal portable binary data format, and java classes, data and geometry can be packed into one jar file, e.g. to ship it to a client. The second version is transparently integrated in the GUI of the CAPRI modelling system.

Swing is used for the GUI in order to profit from the most simple implementation, the viewer has been written completely new, and is not based on existing GIS libraries. Even certain standard JAVA classes as e.g. for hash tables, have been replaced by own implementations, to reduce implementation overhead. Some care was given to support flexibility in classification, given that only quantities are supported, so that the tool covers natural breaks, quantiles, equal spread, mean standard and nested means. Area weighting is supported as well.

In order to export data to other applications, the tools support first of all tab delimited clipboard export, allowing import e.g. into EXCEL. Maps can be exported as JPEGs over the clipboard. Alternatively, the user may export to external file, in CSV format, DBF, to MS Access or to GAMS. DBF export will generate a second file comprising meta data.

The exploitation tools of CAPRI build on a rather simple structure. Each CAPRI work step stores its results as a GAMS parameter, representing a multi-dimensional sparse cube which is stored as a GDX file. The exploitation loads the non-zeros from one or several GDX files into memory. However, given the length of the different dimensions and the use of short codes, the user would be typically lost on his own in the large tables. The XML definition file is the equivalent of a collection of “SQL queries” as it defines views which combine filters in the dimensions of the cube with information on how to show the results (pivot, table, graph or map).

Views as the basic concept for exploitation

The concept of the CAPRI exploitation tools is centred on the idea of a view. Content wise, each view may be understood as showing one or several indicators relating to results of

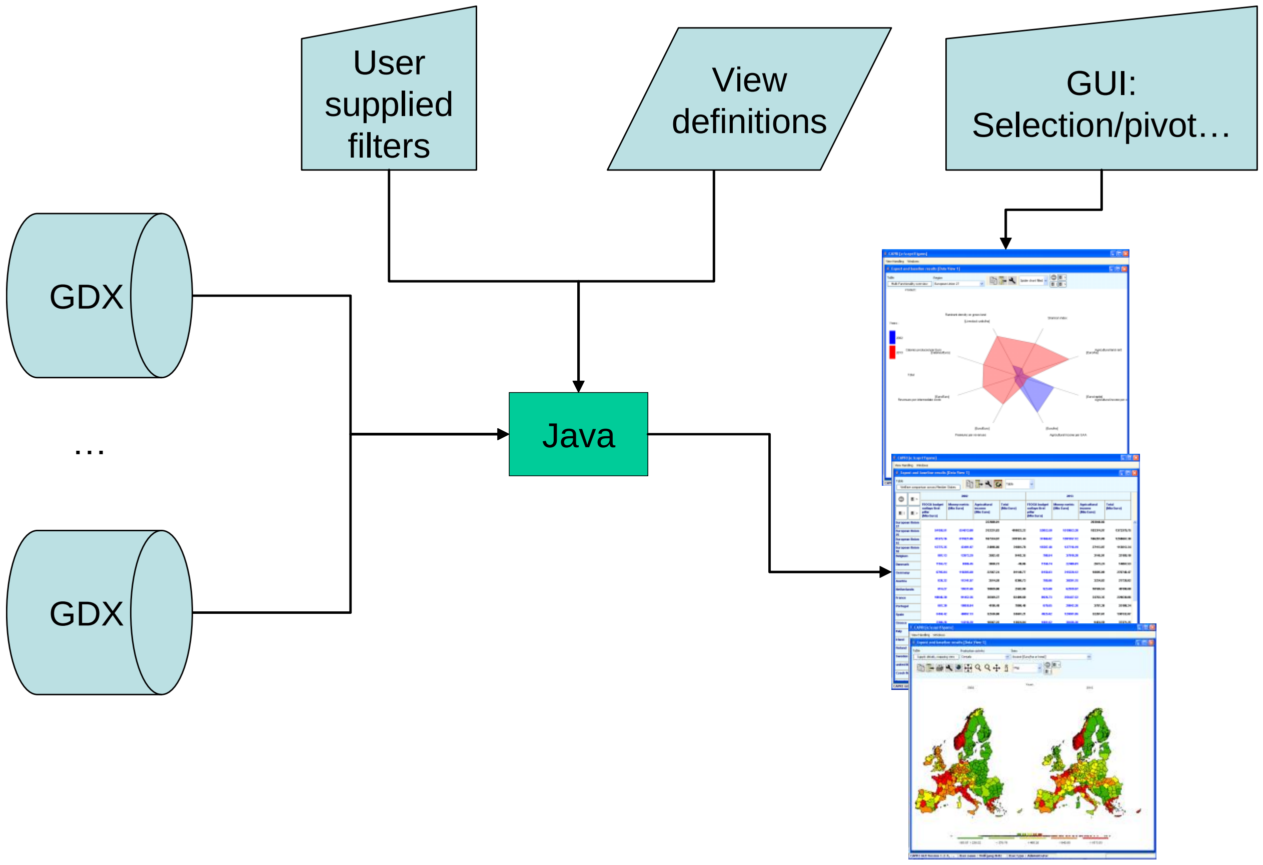
CAPRI working steps, e.g. environmental effects of farming, prices or market balances. Each view thus

- extracts a certain collection of numerical values
- labels them so that they carry information to the user (long texts, units)
- chooses a matching presentation – as a table, map or graphic
- and arranges them in a suitable way on screen.

The views can be linked to each others, allowing a WEB like navigation through the data cube. Views can be grouped to themes. The user may open several views in parallel, and he may change the views interactively according to its needs, e.g. switch from a map to a tabular presentation, or change the pivot of the table, sort the rows etc.

Internally, each view is stored in a XML schema. Technically, a view can be understood as a combination of a pre-defined selection query, along with reporting information. The XML schema allows to attach long texts, units and tooltips to the items of a table, and thus to show meta-data information to the user. The XML schema does hence replace look up tables in a DBMS. It may equally store information regarding the pivoting, the view type (table, map, different graphic types), and for maps, classification, colour ramp and number of classes. The views can be grouped into logical entities, and are shown as a popup menu to the user.

Tabular views may feature column and row groups. Empty columns and rows can be hidden; tables can be sorted by column, with multiple sort columns supported. Numerical filter can be applied to columns.



Why a XML definition files for views?

The exploitation tools of CAPRI build on a rather simple structure. Each GIGG task can store its results as GAMS parameter representing a multi-dimensional sparse cube and save it on disk as a GDX file. The exploitation loads the non-zeros from one or several GDX files into memory. However, given the length of the different dimensions and the use of short codes, the user would be typically lost on his own in the large tables, which can comprise several million non-zero data and basically an unlimited amount of zero cells. The XML definition file defines the views explained above, and allows a structured and user-friendly way to exploit the results of the different work steps. It also separates raw data from the views and from the GUI code itself, which requires relatively little information about the underlying data and their structure besides what is provided by the definition files. XML is an industry standard to store structured information in non-binary text files, which explains why that format was chosen.

The structure of the XML definition files for the views

General comments

It is not intended to let the user edit this file, but in order to have a complete documentation, some information about the structure is included in here. The XML parser used by the GUI's java code is not a general XML parser, as tests revealed that the java base general XML parsers were rather slow. For the XML file used for the definition the views (the standard name is "tables.xml"), using a simple parser has some consequences: only one tag is allowed per line, and tags are not allowed to span several lines. Also, error handling is so far only rudimentary as users are not supposed to edit that file.

The table viewer currently supports up to 6 dimensions, which are named as:

1. Region
2. Activity
3. Product
4. Scenario
5. Year
6. Dim5

in the XML-file. These "logical dimensions" can be mapped to any dimension of the original data cube read in by the java code. Pivoting can then be used to map these "logical" dimensions to viewport dimensions seen by the user such as the columns and rows of a table.

Necessary tags for tables

A table definition is found between the <table> … </table> tags. It must at least define:

- The table theme, such as <theme>Welfare</theme>. The themes are shown as a drop-down menu in the exploitation tools.
- The table name, such as <name>Welfare comparison between Member States</name>. The names must be unique.
- The items of the tables.

The order of the themes and table names will define their order in the drop-down menu.

Defining the items of the table

The underlying idea of having a “hand defined” list of items for one of the definitions stems from the observation that most tables have only a very limited number of columns, and that these are normally formatted with care regarding their text comprised. Each table therefore requires a definition of items, but the items must not necessarily be mapped in the column viewport.

```
  <item>
     <itemName>Money metric</itemName>
     <key>CSSP</key>
     <unit>Mio Euro</unit>
     <longtext>Consumer welfare measurement: expenditures necessary to reach utility in
current simulation under prices of reference scenario</longtext>
     <link>Money metric</link>
  </item>
```

An item definition is enclosed in the <item>…</item> tags. It must at least comprise a <key> and an <itemName> tag. The case sensitive key must match the symbol identifier as found in the GDX file, whereas the itemName can be freely chosen.

Facultative tags are:

<unit>: a physical unit shown in table

<longtext>: a text shown when the mouse hovers of the column

<link>: a link to another table for the table cells under the column.

<colormode>: the color mode used when a map is drawn for the item. The following modes are supported:

•	GYR	Green Yellow Red
•	RYG	Red Yellow Green
•	GR	Green Red
•	RG	Red Green
•	BG	Blue Green

- GB Green Blue
- WB White Black
- BW Black White
- LD Light Blue Dark Blue
- DL Dark Blue Light Blue

<eval>: the item is calculated from other items, e.g. <eval>VAL + VAL[*,BlueBox,*,*,*,*] + VAL[*,DeMinimis,*,*,*,*]</eval>

In order to define from which dimension they are taken, the user can set either:

<itemDim>region</itemDim>

Deprecated is the old style:

<isActivity>NO</isActivity>

Which means that the table loops over the products, and the items refer to the activity dimension. A typically example is a table with market balance elements: items such as "FEDM" are found in the columns of the CAPRI tables where also the activities are stored. Consequently, the table will loop over the products, and not over the activities. Alternatively:

<isActivity>YES</isActivity>

allows only items from the product dimension, and lets the table loop over the activities. A typical example provides a table showing activity levels, yield or economic indicators for the production activities.

Additional tags: <subTheme>

Allows to introduce sub-themes in the table selection.

Additional tags: <defpivot>

Defines the default pivot used for the table. The pivot string consists of characters. The first character position is for the table row blocks, the second for the table rows, the third for the column blocks and the last for the columns. The logical dimensions are labelled with the following characters:

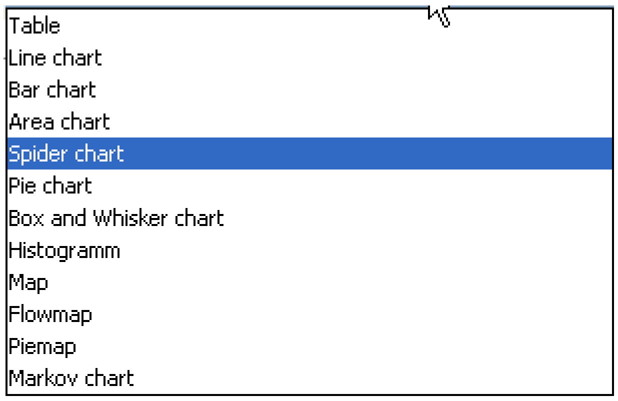
A	Activity
D	Dim5

I	Items
M	Activity and Product merged
P	products
Q	Year and dim5 merged
S	Scenario
R	regions
X	Region and dim5 merged
5...9	Dim5 ... Dim9

The definition <defpivot>0R0S</defpivot> thus means: regions are in the rows, scenarios in the columns. The definition <defpivot>PISR</defpivot> puts the products in the row blocks, the items in the rows, the scenarios in the column blocks and the regions in the columns.

Additional tags: <defview>

Defines the default view used for the tables, the list of default views is equal to what the user can select in the drop-down box:



Additional tags: <COO>

This tag defines the geometry to use for maps. Currently, the following geometry files are available:

NUTSII.zip	NUTS 2 geometry for countries covered by the supply module
MS.zip	NUTS 0 geometry for the countries covered by the supply module

RMS.zip	Global geometry for the regions with behavioural functions in the market model
RM.zip	Global geometry for the trade blocks in the market model
HSMU.zip	1x1 km pixel clusters for EU 27 without Malta and Cyprus

There are also 1x1 km pixel clusters for individual Member States, but these are internally passed to the viewer when only one country is shown.

Alternative texts for the dimensions

Normally, the names for the dimensions are passed in the view by Java. However, their name can be changed by:

<regionText>….</regionText>

<activityText>…<activityText>

<regionText>…<regionText>

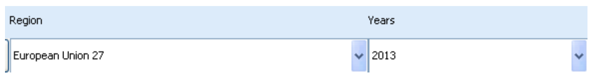
<productText>…<productText>

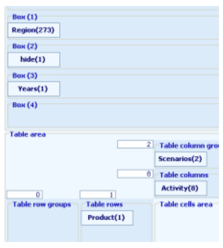
<scenText>…<scenText>

<dim5Text>…<dim5Text> ... <dim9Text>…<dim9Text>

<yearText>…<yearText>

That text is shown:

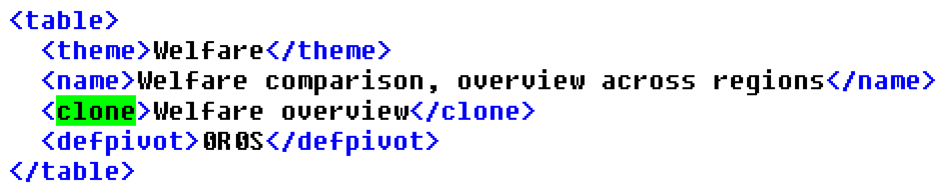
- As description above the outer drop-down selection boxes: 

- In the pivot dialogue: 

- And in gaphics / map titles and the like.

Additional tags: <clone>

The tag uses the item and other definitions from another table, and can be used e.g. to show the same selection in a different pivot or view types, e.g:

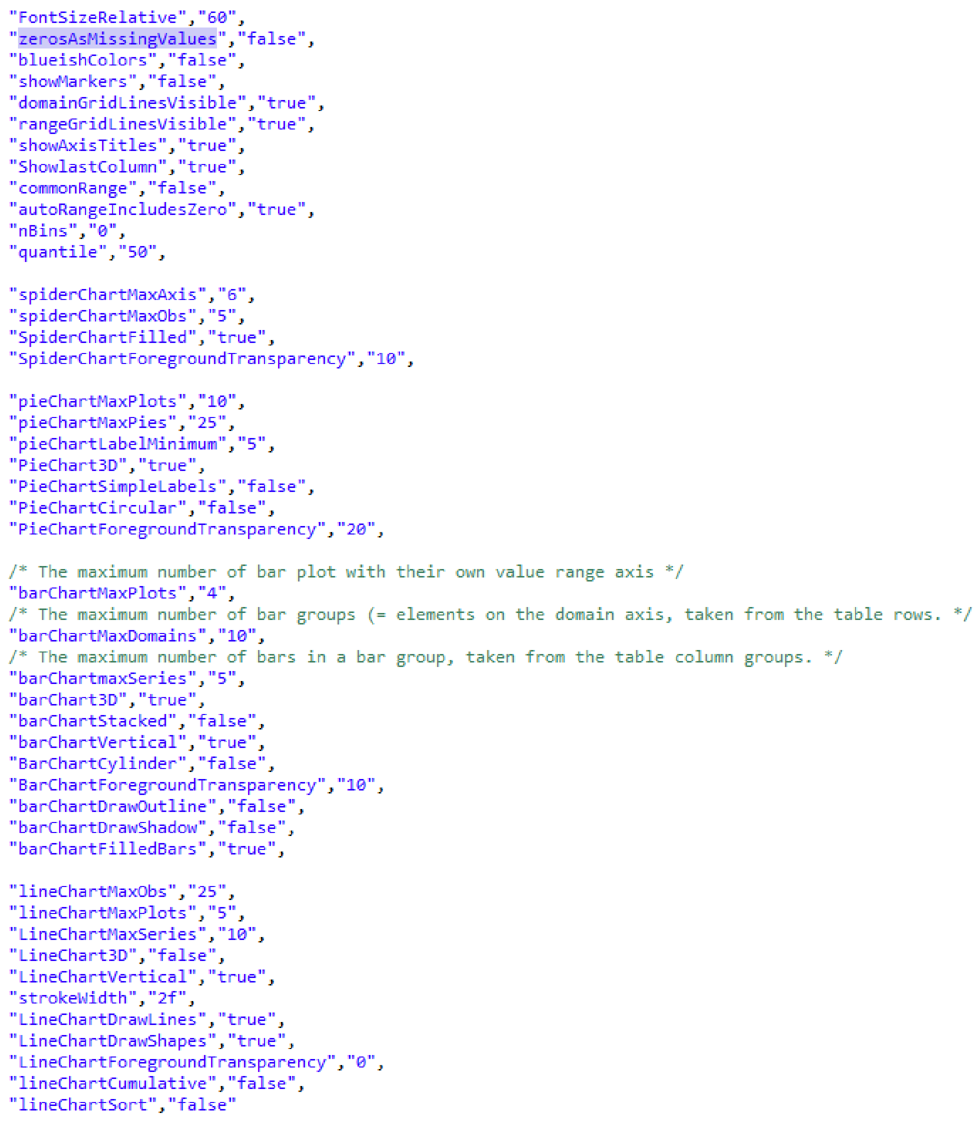


```
<table>
  <theme>Welfare</theme>
  <name>Welfare comparison, overview across regions</name>
  <clone>Welfare overview</clone>
  <defpivot>0R0S</defpivot>
</table>
```

The clone tag *must* immediately follow the name tag, as otherwise, preceding definitions are lost.

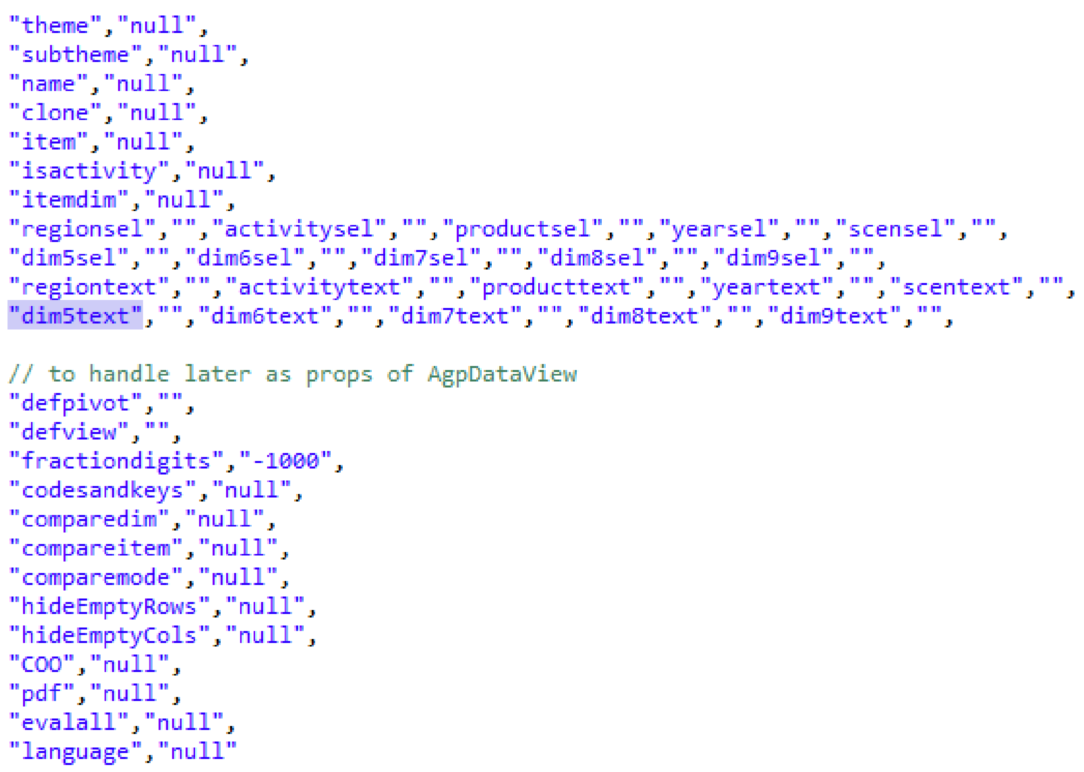
Further tags

There is a longer list of further tags which refer e.g. to definitions of graphs. They are here only listed with there default settings without a detailed explanation



```
"FontSizeRelative","60",
"zerosAsMissingValues","false",
"blueishColors","false",
"showMarkers","false",
"domainGridLinesVisible","true",
"rangeGridLinesVisible","true",
"showAxisTitles","true",
"ShowlastColumn","true",
"commonRange","false",
"autoRangeIncludesZero","true",
"nBins","0",
"quantile","50",

"spiderChartMaxAxis","6",
"spiderChartMaxObs","5",
"SpiderChartFilled","true",
"SpiderChartForegroundTransparency","10",

"pieChartMaxPlots","10",
"pieChartMaxPies","25",
"pieChartLabelMinimum","5",
"PieChart3D","true",
"PieChartSimpleLabels","false",
"PieChartCircular","false",
"PieChartForegroundTransparency","20",

/* The maximum number of bar plot with their own value range axis */
"barChartMaxPlots","4",
/* The maximum number of bar groups (= elements on the domain axis, taken from the table rows. */
"barChartMaxDomains","10",
/* The maximum number of bars in a bar group, taken from the table column groups. */
"barChartmaxSeries","5",
"barChart3D","true",
"barChartStacked","false",
"barChartVertical","true",
"BarChartCylinder","false",
"BarChartForegroundTransparency","10",
"barChartDrawOutline","false",
"barChartDrawShadow","false",
"barChartFilledBars","true",

"lineChartMaxObs","25",
"lineChartMaxPlots","5",
"LineChartMaxSeries","10",
"LineChart3D","false",
"LineChartVertical","true",
"strokeWidth","2f",
"LineChartDrawLines","true",
"LineChartDrawShapes","true",
"LineChartForegroundTransparency","0",
"lineChartCumulative","false",
"lineChartSort","false"
```

The following list further tags, partially explained above:



```
"theme","null",
"subtheme","null",
"name","null",
"clone","null",
"item","null",
"isactivity","null",
"itemdim","null",
"regionsel","","activitysel","","productsel","","yearsel","","scensel","",
"dim5sel","","dim6sel","","dim7sel","","dim8sel","","dim9sel","",
"regiontext","","activitytext","","producttext","","yeartext","","scentext","",
"dim5text","","dim6text","","dim7text","","dim8text","","dim9text","",

// to handle later as props of AgpDataView
"defpivot","",
"defview","",
"fractiondigits","-1000",
"codesandkeys","null",
"comparedim","null",
"compareitem","null",
"comparemode","null",
"hideEmptyRows","null",
"hideEmptyCols","null",
"COO","null",
"pdf","null",
"evalall","null",
"language","null"
```

Filters for the elements in the different dimensions

Without filters, all elements found on a logical dimension will be shown to the user in any table. The exemptions are the items either defined for the product or the activity dimension, see above. In order to restrict the selection in the other logical dimensions, a selection list can be defined in the table definition. Take as an example the following XML tag:

<regionSel>MS<regionSel>

It means that the table will only show elements with the tag <region> (see below) which comprise MS in their <sel> field. The example would refer to the Member States. There is a specific selection list:

<regionSel>FromDataCube<regionSel>

Which will neglect the elements under <region> as defined in the file, but rather takes any one found in the data cube. The option was introduced to avoid the necessity to define all 180.000 HSMU codes in the file.

Alternatively, a regex string can be used, e.g.

<dim5Sel>red[0-9]+_regex</dim5Sel>

Attaching long texts and filters to elements

Items for activities, products, regions and dim5 are typically defined in the file, see the following example:

```
<region>
  <key>SK020038</key>
  <itemName>SK020 - FT41 / GT100 - Specialist dairying (FT 41)</itemName>
  <sel>[all, RS, SK, FA, SKFA, FT41, GT100, FT41GT100]</sel>
 </region>
```

The definitions for one item are enclosed in the tag (<region>…</region>, <activity>…</activity>, <product>….</product>, <dim5>…</dim5>).

The order of the items in the tables is defined by these lists.

Each item has a key, which corresponds to the symbol identifier found in the GDX file. The keys are case sensitive. The itemName is a long text which is typically shown to the user. The elements found between the <sel> …</sel> tags can be used as filters in table definitions, or interactively by the user.

A specific tag is <aggreg>yes</aggreg>. When found for an item in the rows, it will be shown twice in the table: once in the top part, and then again.

The structure of the GAMS generated gdx files used by the exploitation tools

The exploitation tools load directly the gdx-files generated by the GAMS processes linked to the tasks described above. The gdx-files only store non-zero numerical values. The main content of a gdx file are two types of records. The first type provides a list of all labels used to identify the numerical data in the gdx file as GAMS does not support numerical indices, but requires character labels. The list does not distinguish for which data dimensions the labels are used. They are hence typically a mix of product, activity, region and further labels. The second type of records belongs to GAMS parameters (scalars, vectors, or multi-dimensional tables). Each non-zero numerical item in each parameter has its own record. Each of these records provides the numerical data in double precision (depending on the parameter type there may be different data stored in one record, as for variables its upper and lower bound, current level and marginal value etc.), and a vector of indices pointing in the list of codes described above.

Loading the data from gdx files

The data matrices generated by the different tasks as described above and stored in gdx-files are typically rather sparse, so that it seemed appropriate to load the data from the gdx-file into hash tables for exploitation purposes. That is done in a two step procedure. In the first step, all records from the gdx file are read and vectors of all found indices are stored. The length of each data dimension is only known when all data records are read, and is equal to the number of unique indices for each dimension. Once all records are read, the final length of these index vectors then defines a linear index room for the multi-dimensional table. In a second step, the records are read again, and the index vectors for each record now allow to define a linear index in the total table. A hash code is derived from that linear index to store the numerical values into a hash table. As the number of items to store in the hash table is known beforehand, a rather simple hash table implementation can be used. If necessary, step one can be run over several parameters which may be hosted in several gdx files, so that results from different runs can be merged into one hash table.

As the gdx-files provide lists of all labels used in any parameters stored in that gdx-file, the index vectors allows to build lists of labels linked for each index in a data dimension. There exists an additional storage type in the gdx-files to retrieve long-texts to the labels as defined in GAMS set definitions. However, one label may occur in different sets with different long texts, and the gdx-file does not store a possibly user defined relation between a data dimension of a parameter and a specific set, an option termed domain checking in GAMS. In order to link hence long-texts to the labels used for a specific data dimension, two options are possible. Firstly, at run time the user may interactively re-establish the link between data dimensions and specific sets, and thus add long-texts to the labels used on that data dimension based on his knowledge. Or the relation may be hard coded in the JAVA code.

Menu bar

GGIG allows to add two types of menu items to the menu bar: HTML links and e-mail sent:

```
<helpmenuitem>
         <name>View capri web page</name>
         <value>http://www.capri-model.org</value>
</helpmenuitem>


<helpmenuitem>
         <name>Send mail to capri user list</name>
         <value>capritalks@ilr.uni-bonn.de</value>
         <type>mail</type>
</helpmenuitem>
```

Design hints for structured programming in GAMS with GGIG

Using information passed from GGIG

As seen above, GGIG passes information mostly via $SETGLOBAL settings. That has the advantage that the GAMS coder is rather free how to use the information. Take the following example (which could be generated from a slider):

```
$SETGLOBAL STEPS 99.0
```

There a several ways to use that information in GAMS code, below are a few examples:

1. Round the setting to an integer with $eval in GAMS and use it in a set definition:

```
$eval steps round(%steps%)
set step / S1*%STEPS% /;
```

2. Use it in an combined definition and declaration statement for a scalar

```
scalar s_steps / %STEPS% /;
```

3. Use it in assignment

```
p_control("Steps") =  %STEPS%;
```

4. Use it for pre-compiler conditions:

```
$eval steps round(%steps%)
$ifthen %steps% == 1
```

5. Use for GAMS program controls

```
  if ( %STEPS% > 10,
  );
```

Structure your program by tasks

The following example shows how the concepts of tasks can be used on conjunction with includes to structure a top-level program

```
* -----------------------------------------------------------------------------
*
* (4) ESTIMATE CONSTANT TERMS
*
* -----------------------------------------------------------------------------

$iftheni "%task%" =="Estimate constant terms"

$include 'est_const.gms'

$endif
*
* -----------------------------------------------------------------------------
*
* (5) ESTIMATE CONSTANT TERMS AND TREND PARAMETERS
*
* -----------------------------------------------------------------------------

$iftheni "%task%" =="Estimate constant terms and trend parameters"

$include 'est_const_and_trend.gms'

$endif
```

The basic idea is to have a common a part which is shared by many tasks and then blocks which perform task specific operations. As the "$iftheni ... $endif are working at compile time, not used code is excluded even from compilation which helps to save memory and reduce the size of the listing.

One entry points for run specific settings

A typical problem with more complex economic simulation models defined in GAMS is the steering of scenarios. GGIG pushes the GAMS developer to a code structure where all run specific settings are entered via the single include file generated by GGIG. That does not imply that all data for a specific scenario are comprised in the include file. It could e.g. mean that the user has selected via the interface the include file(s) with specific settings and that the names of these files are passed via the include file to GAMS.

Scenario editor

The scenario editor is an optional tool to be embedded in a GGIG user interface which supports the user in setting up run specific include files where the content is *not* stemming from GUI controls. That parallel way to define run specific input is typically necessary for more complex tools where e.g. policy scenarios are defined in GAMS code.

The scenario editor is a “predefined” task which must be named “Define scenario”, e.g.

```
<task>
         <name>Define scenario</name>
         <userLevls>runner,Administrator,developper,debugger</userLevls>
</task>
```

A related setting stores the directory where the input files are found:

```
<scenarioDir><attr>scen</attr></scenarioDir>
```

Batch execution

The batch execution facility is a tool which:

- Allows executing many different tasks after each other without requiring user input.
- Reports the settings used, any errors and GAMS result codes in a HTML page from which they may queried at a later time.
- Ensures that each new run generates its own listing file, which can be opened from the HTML page.
- Allows storing the output of the different runs in a separate directory, while reading input from unchanged result directories.

The purpose of the batch execution facility is therefore at least twofold. On the one hand, it allows setting up test suits for the GAMS code of a project such as checking for compilation without errors for all tasks and different settings such as with and without market parts etc. Secondly, production runs of e.g. different scenarios can be started automatically. Timer facilities allow starting the batch execution at a pre-scheduled time. Along with functionalities to compare in a more or less automated way differences in results between versions, the batch facility is one important step towards quality control.

Generate GAMS documentation

The GUI comprises a tool to generate for each GAMS file and each symbol used HTML pages which are interlinked. For details on the code documentation facility see the technical document "Javadoc like technical documentation for CAPRI" to be found on the Capri web page under technical documents.

The controls on top allow the user:

- To define in which directory the "EXP", "REF" and "GDX" files are stored which serve as input into the documentation generator.
- To choose the directory where the HTML files will be generated.
- To select the tasks covered by the documentation generator.

Background

System such as CAPRI have grown over years to a rather complex (bio-)economic modelling system. Its code based includes hundredth of single GAMS files, and ten thousands of lines. Not only newcomers face the challenge to get an overview about dependencies in the huge code base and to link the technical implementation to methodological concepts and documentation. On top, the large-scale character of CAPRI often asked for technical features in the GAMS code which are far from the solution chosen for tiny examples as often presented in courses, as the wide spread usage of dynamic sets, conditional includes, the usage of $batcinludes or the application of the grid solve feature.

The task of documenting and keeping an overview of the CAPRI code base is certainly not eased by the fact that basically any object in GAMS has global scope. The concept of functions of subroutines underlying many other programming languages with clearly defined lists of variables passed in and out is not implemented in GAMS. Encapsulation and modularisation are hence not naturally supported by GAMS. That also renders automated documentation of the code more challenging compared to other languages.

Since quite a while, CAPRI user community discusses about some refactoring of the code base on more clearer coding standards with the aim to ease code maintenance, documentation and further development. That refactoring should also cover standard for in-line documentation, including a better link to the methodological documentation. The project CAPRI-RD which will most probably start in spring 2009 will attack some of these tasks in specific working packages. But clearly, that will only become success if the underlying concept is generally accepted and implemented by the community of CAPRI developers. That means that the value added of following coding and documentation standards must be visible to any developer.

The paper is thought to open the discussion and trigger feedback about how to generate an easy to maintain and useful technical documentation for CAPRI, based on the example of JAVADOC (http://de.wikipedia.org/wiki/Javadoc). It is organized as follows. The next short paragraphs will list desired properties of a technical documentation for CAPRI, followed by a more detailed discussion of a proposal for an implementation which is working as a prototype. The last chapter will then show selected screenshots.

Desired properties

The main properties a automated technical documentation of a tool under GGIG such as CAPRI should fulfil are as follows:

- Avoiding redundancies, i.e. information should whenever possible only inputted once. Specifically, selected comments added in-line in the code should be ported over to the technical documentation.
- Changes in the code structure should possibly be reflected automatically
- The documentation must be able to reflect different GAMS projects (CAPMOD, CAPREG ..) and to differentiate between instances of the same project (CAPMOD in basline or calibration mode …).
- Its biggest part of the technical documentation should be constructed directly from the code based in an automated way.
- It should also collect information from the SVN versioning system

Technical implementation

The main ingredients of the proposed implementation are as follows:

- The final format of the technical documentation is based on automatically generated static HTML pages, following the example of JAVADOC, with some JavaScript to allow for collapsible trees
- The methodological documentation will continue to be edited in Word, and converted into a PFD-document. It will comprise references to GAMS sources (individual

GAMS files) or even GAMS objects (variables, equations, models, parameters). Those references can be addressed in the GAMS code, and the HTML pages will allow opening the PDF-document at the referenced point.

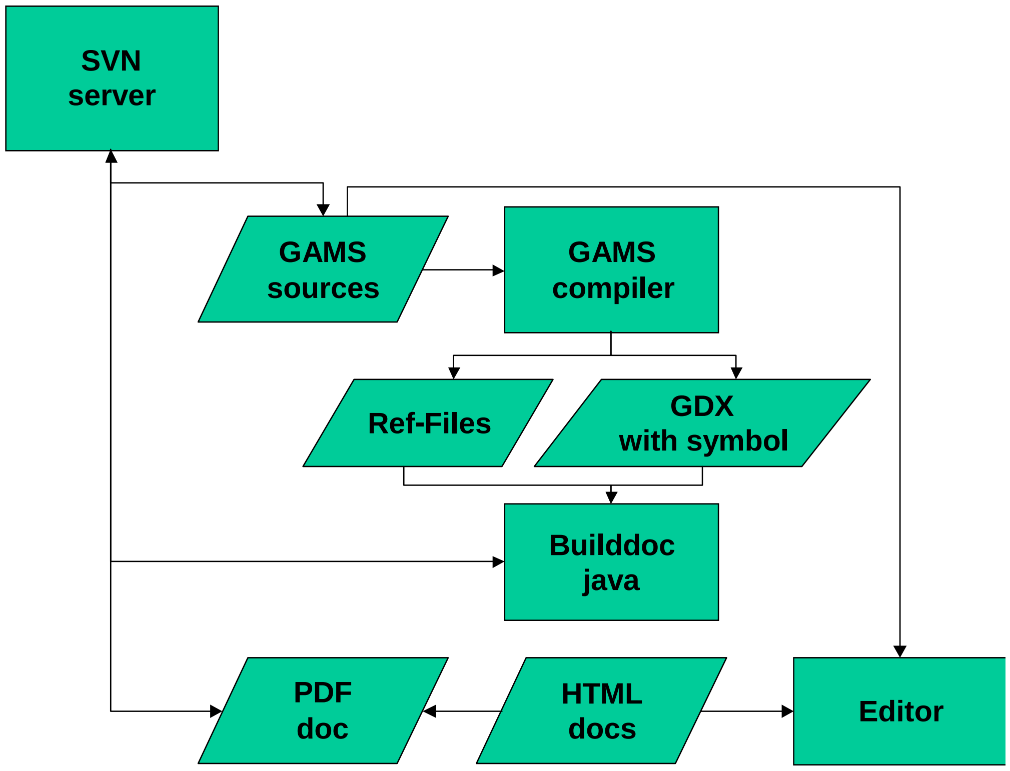
- As with JAVADOC, technical documentation should be edited as in-line comments into the GAMS sources, based on clear in-line documentation standards. Each GAMS source as a file header with standard properties about the file.
- In-line documentation will be mostly based on two levels: the level of individual GAMS files and on the level of individual GAMS objects. In some cases, that may require to break down larger programs in smaller pieces, with a clear task and eventually clear inputs and outputs.

Overview

The following diagram depicts the general approach. The SVN server will host the GAMS sources, the documentation builder (Builddoc) as a Java application and the PDF with the methodological documentation. Users synchronize their local work copies with the server. In order to avoid developing in Java a new parser for GAMS code, the GAMS compiler itself is used to generate the necessary input for the technical documentation. Two different types of files for each “project” or “instance” included in the documentation are used for that purpose so far:

1. So called **“REF” files**, which list information in which files and in which line symbols are declared, defined, assigned and referenced. They also comprise information about long texts and domain of the symbols. The “REF” file can be generated by the argument rf=*filename* when GAMS is called (e.g. ”GAMS capmod a=c rf=capmod.ref”). As the GAMS compiler itself is used, conditional includes and the like are automatically treated as during execution time. That opens also the possibility to include the generation of the documentation in the GUI.
2. **GDX files generated with an empty symbol list at compile time** ($GDOUT module.gdx; $UNLOAD; $GDOUT). The resulting GDX file will comprise all sets, parameters etc. used by the programs, and most importantly, the set elements as declared. The name of the GDX file could be passed as a parameter by the GUI.

Those files hence reflect the actual local code base with any local modification, and can be generated for a specific instances of the projects (e.g. for CAPMOD with and without the market module etc.). A JAVA application named *Builddoc* parses both types of files, on demand for several projects, and generates static HTML pages. The GAMS code comprises in-line comments carrying information about references to the methodological documentation, and the HTML pages comprise calls to the editor to open the actual source code at the local machine, as well as information about relation between the different GAMS Symbols.



Handling of GDX files

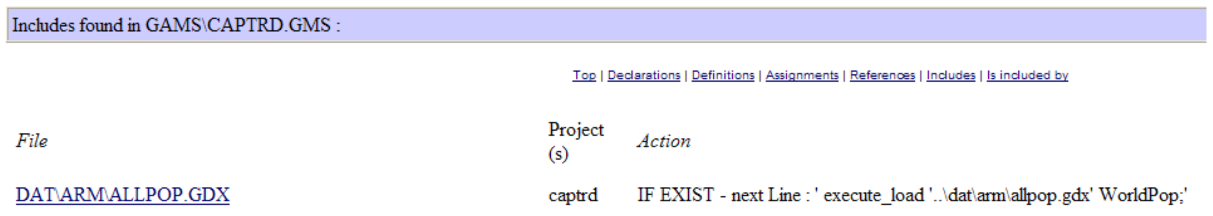
The “expand” option generates information about GDXIN and GDXOUT statements as those are executed at compile time. Consequently, files addressed via GDXIN or GDXOUT are automatically reported in the documentation system.

Hovever, the file does not comprise information about the “execute_load” and “execute_unload” executed at run time. That is quite clear, as the statements may be comprised in program structures as loops or if statements where there are never reached at execution time. We need hence a work around to report those files in the documentation system if we would avoid writing a new GAMS parser.

However, “$IF EXIST” statements are taken into account by the expand command. It is therefore proposed to put an “$IF NOT EXIST” combined with an abort statement before all “execute_load” statements. As seen in:

```
$IF NOT EXIST ..\dat\arm\allpop.gdx $ABORT ..\dat\arm\allpop.gdx is missing
  execute_load '..\dat\arm\allpop.gdx' WorldPop;
```

By doing so, the program will already at compile exit if one of the necessary files is missing. That avoids starting a process and eventually overwriting files which then will stop later due to missing input data. The HTML page will report that sequence as:


Includes found in GAMS\CAPTRD.GMS :

Top | Declarations | Definitions | Assignments | References | Includes | Is included by

File	Project (s)	*Action*
DAT\ARM\ALLPOP.GDX	captrd	IF EXIST - next Line : ' execute_load '..\dat\arm\allpop.gdx' WorldPop;'

The use of “$IF EXIST” in the context of “execute_unload” can only be motivated with the fact to produce code which is better documented. Here, is it proposed to warn the user at run time about the fact that the file is overwritten.

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